FIG. 1

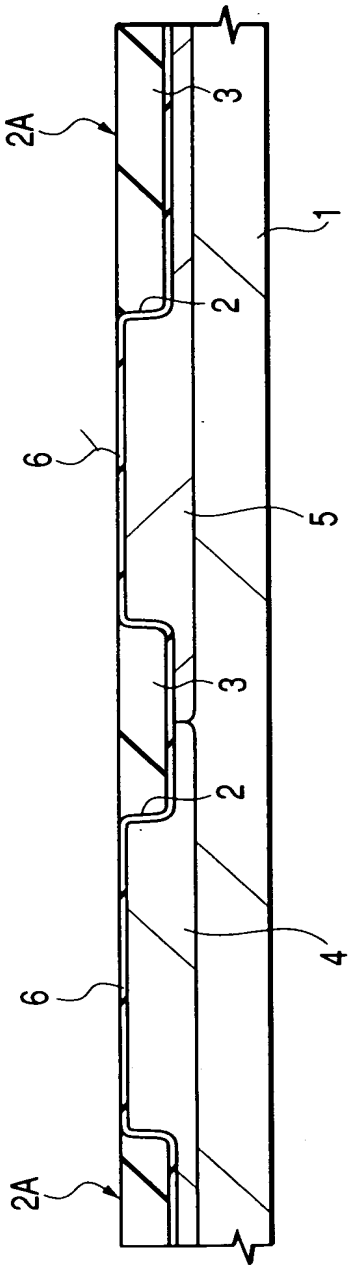


FIG. 2

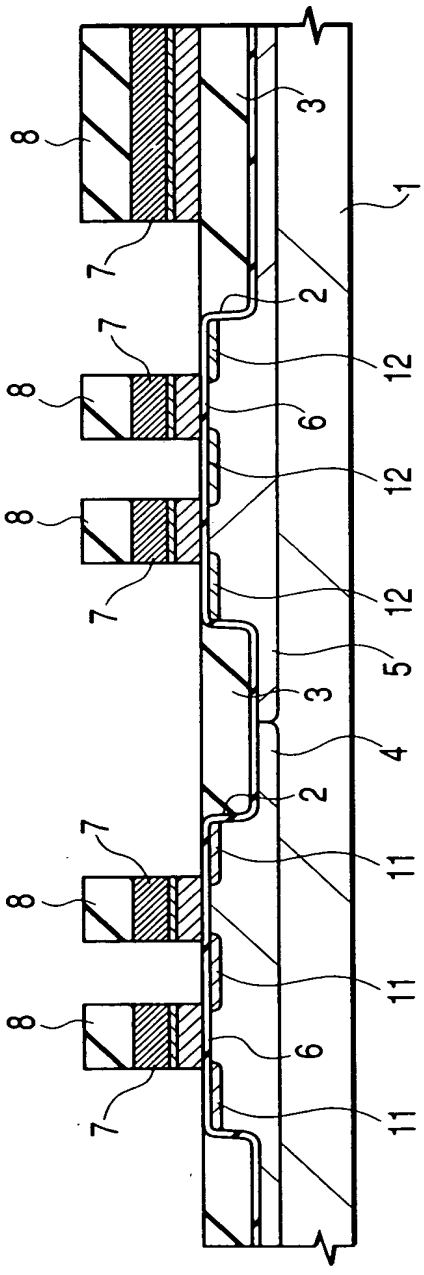


FIG. 3

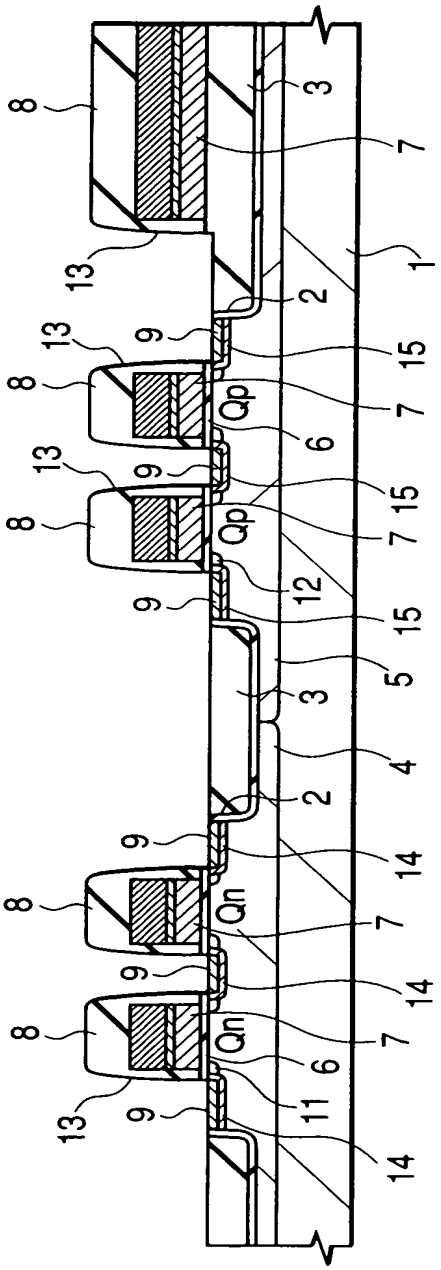

8
13
9
Qp
Qn
7
15
6
12
5
3
4
2
14
11
1

FIG. 4

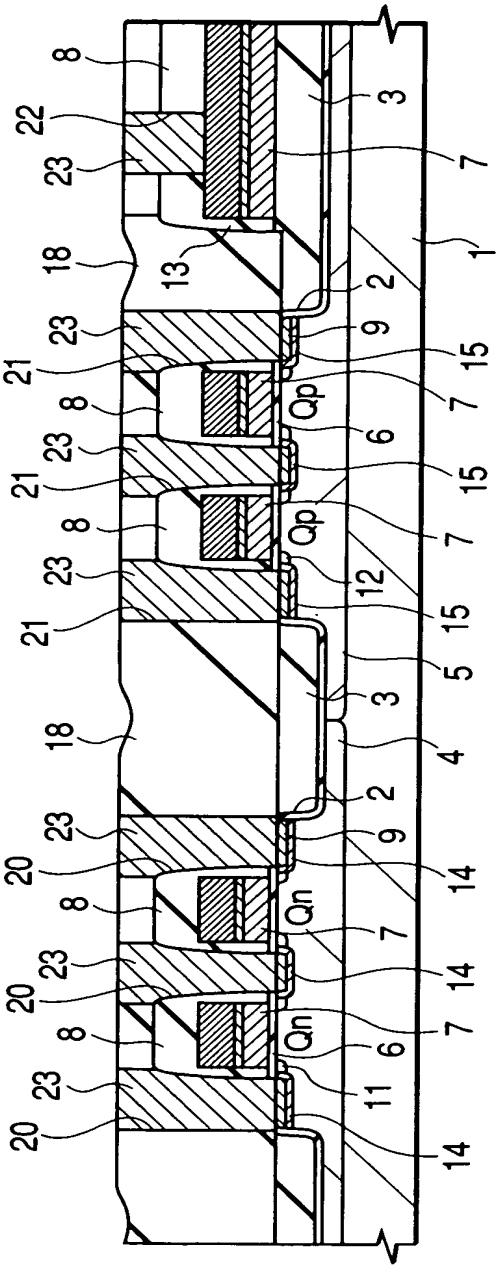

8
22
23
18
13
9
Qp
Qn
7
15
6
12
5
3
4
2
14
11
1
21
20

FIG. 5

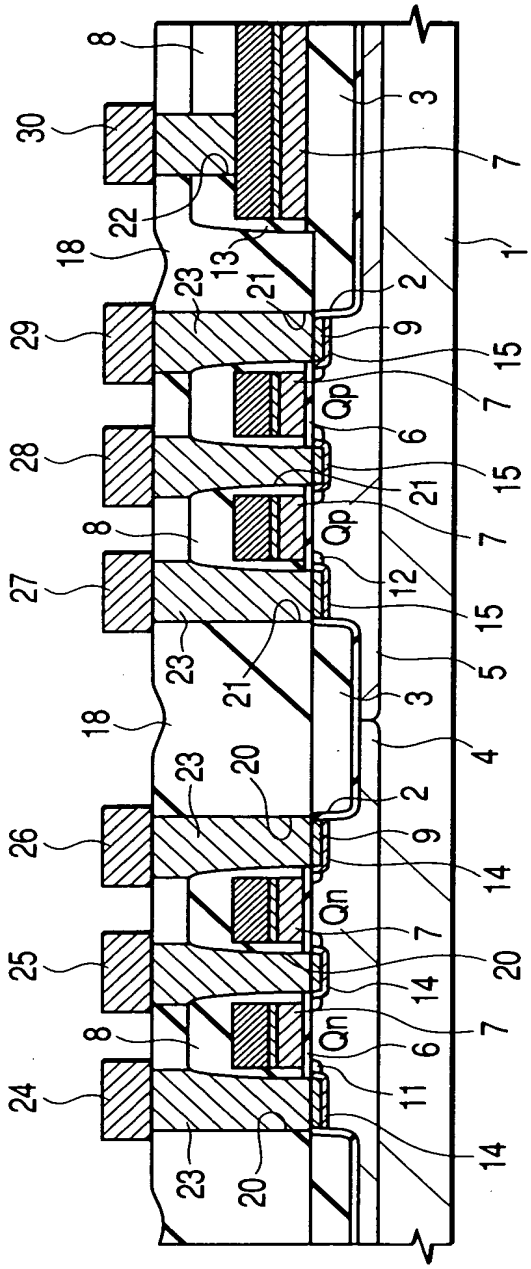

8
30
3
7
22
18
13
21
1
23
2
29
9
15
Qp
7
6
28
21
15
Qp
8
7
27
12
15
23
21
5
3
18
4
23
20
2
26
9
14
Qn
7
20
25
14
8
Qn
7
6
24
11
23
20
14

FIG. 6(a)

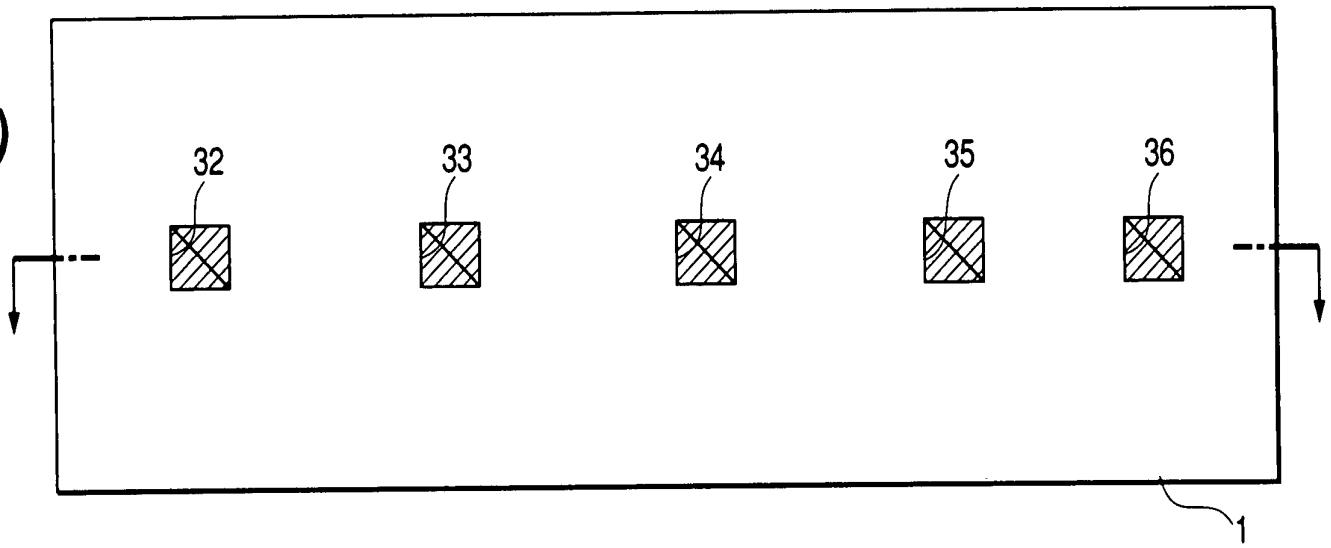
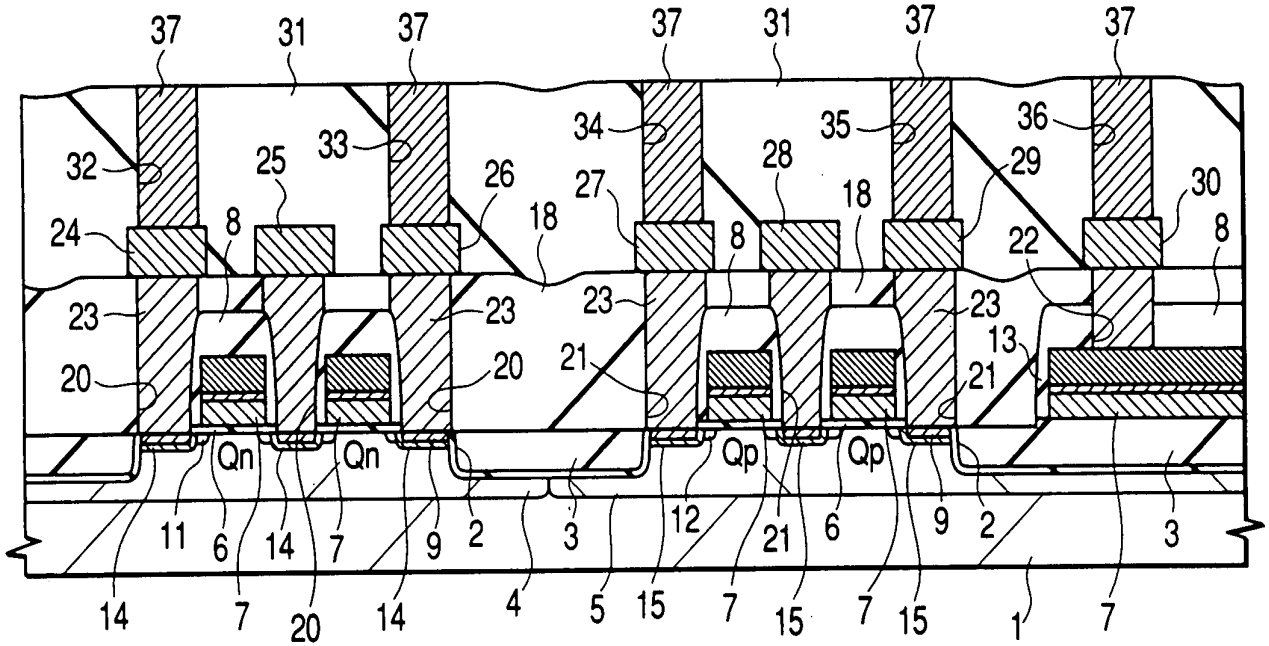

32
33
34
35
36
1

FIG. 6(b)


37
31
32
25
33
26
34
27
35
28
36
29
30
24
8
18
22
23
20
21
13
Qn
Qp
11
6
14
7
9
2
3
12
4
5
15
1

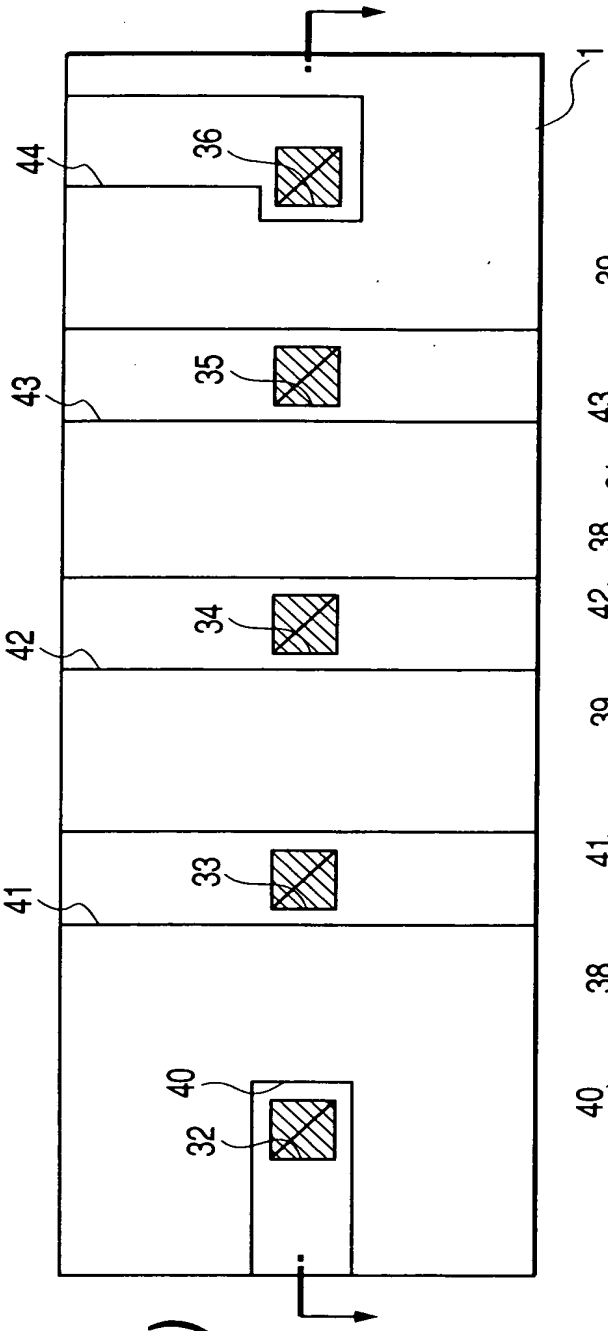


FIG. 7(a)

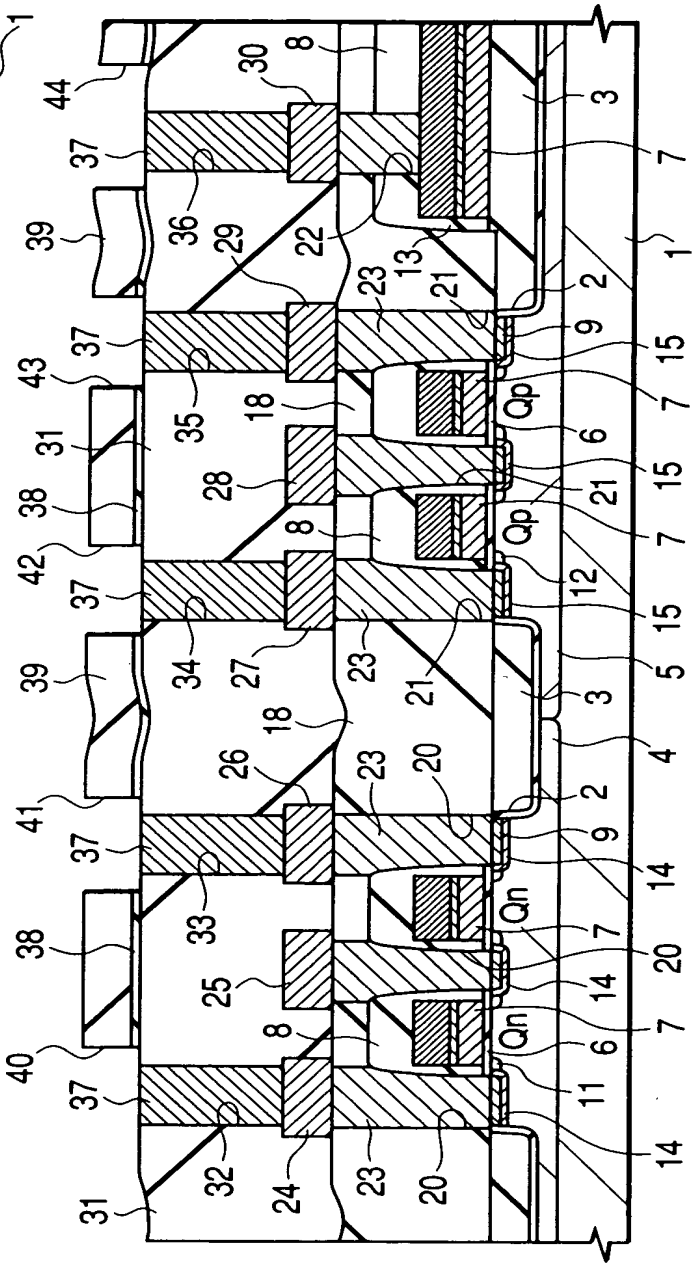


FIG. 7(b)

FIG. 8

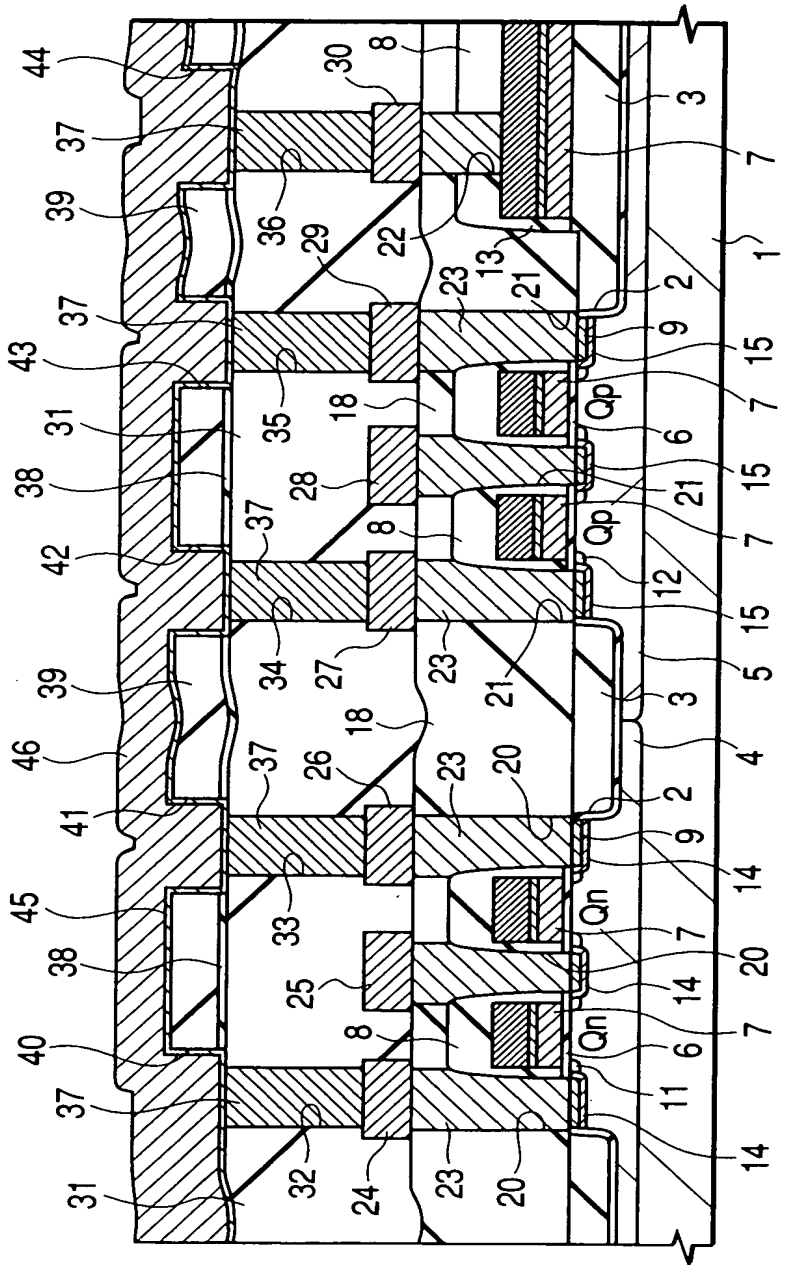


FIG. 9

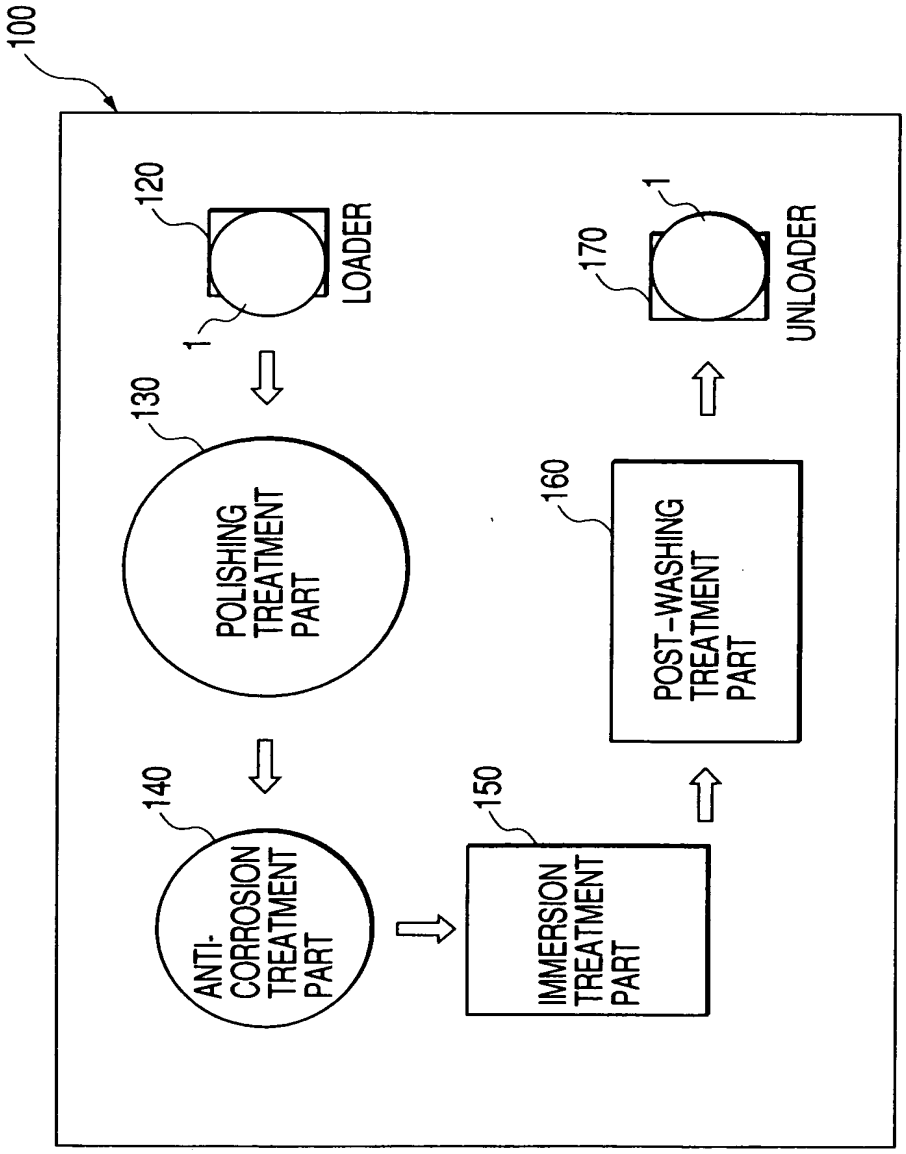

100
120
LOADER
1
130
POLISHING TREATMENT PART
140
ANTI-CORROSION TREATMENT PART
150
IMMERSION TREATMENT PART
160
POST-WASHING TREATMENT PART
170
1
UNLOADER

FIG. 10

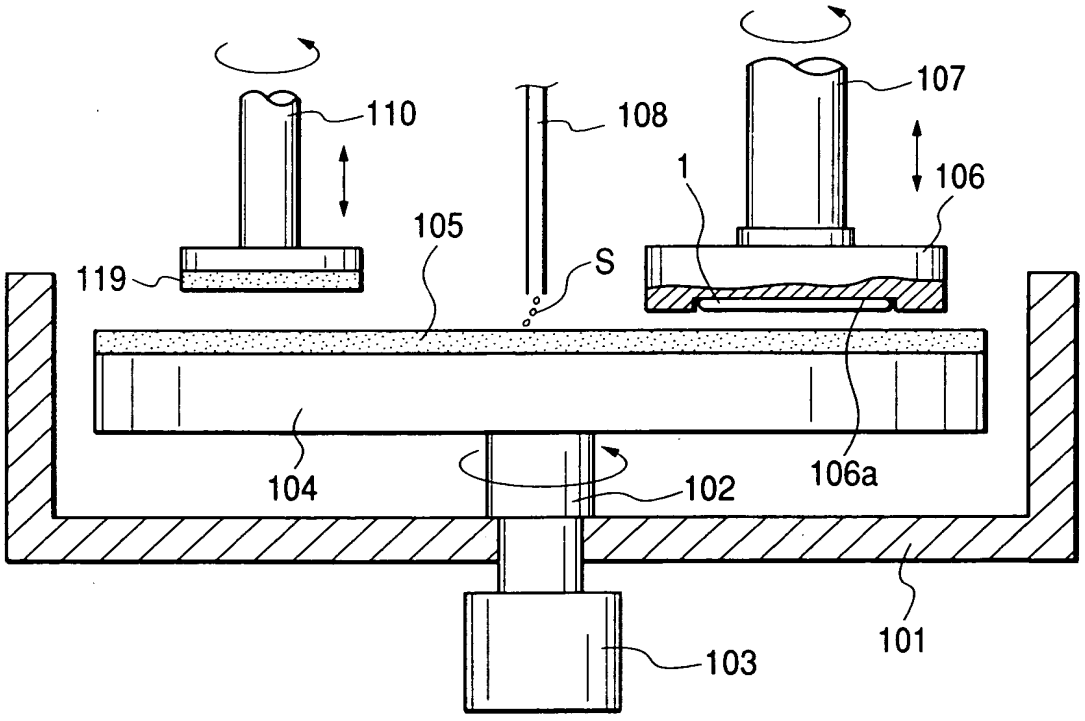


FIG. 11

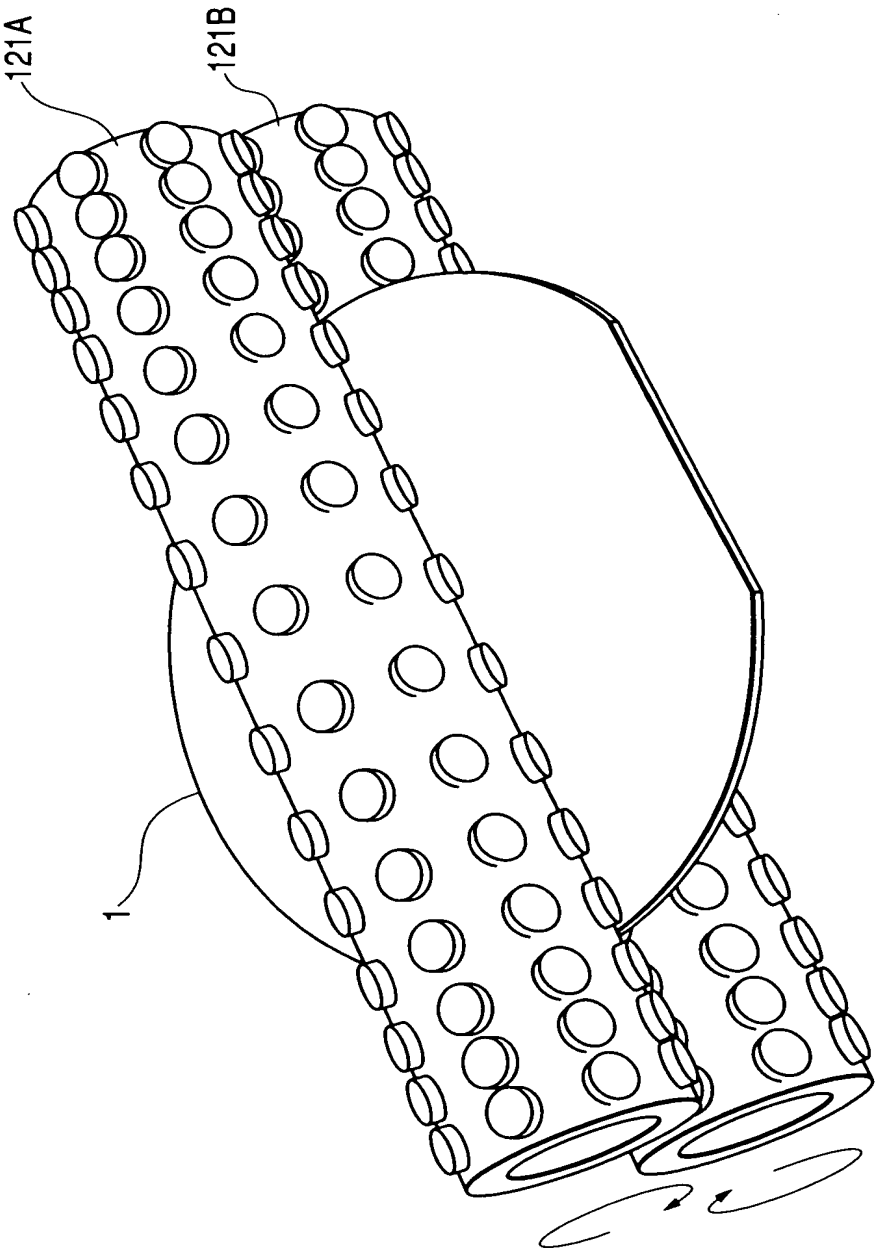


FIG. 12

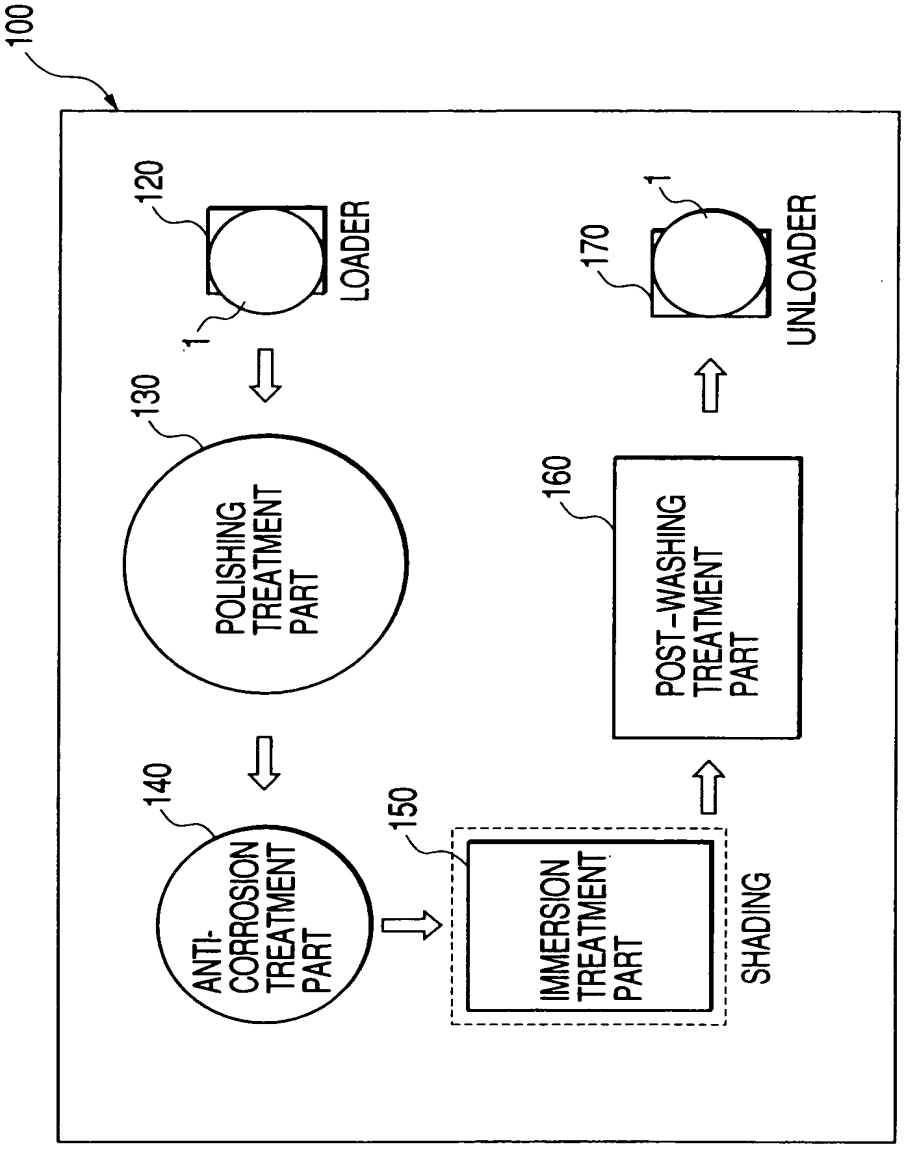

100
120
LOADER
1
130
POLISHING TREATMENT PART
140
ANTI-CORROSION TREATMENT PART
150
IMMERSION TREATMENT PART
SHADING
160
POST-WASHING TREATMENT PART
170
1
UNLOADER

FIG. 13

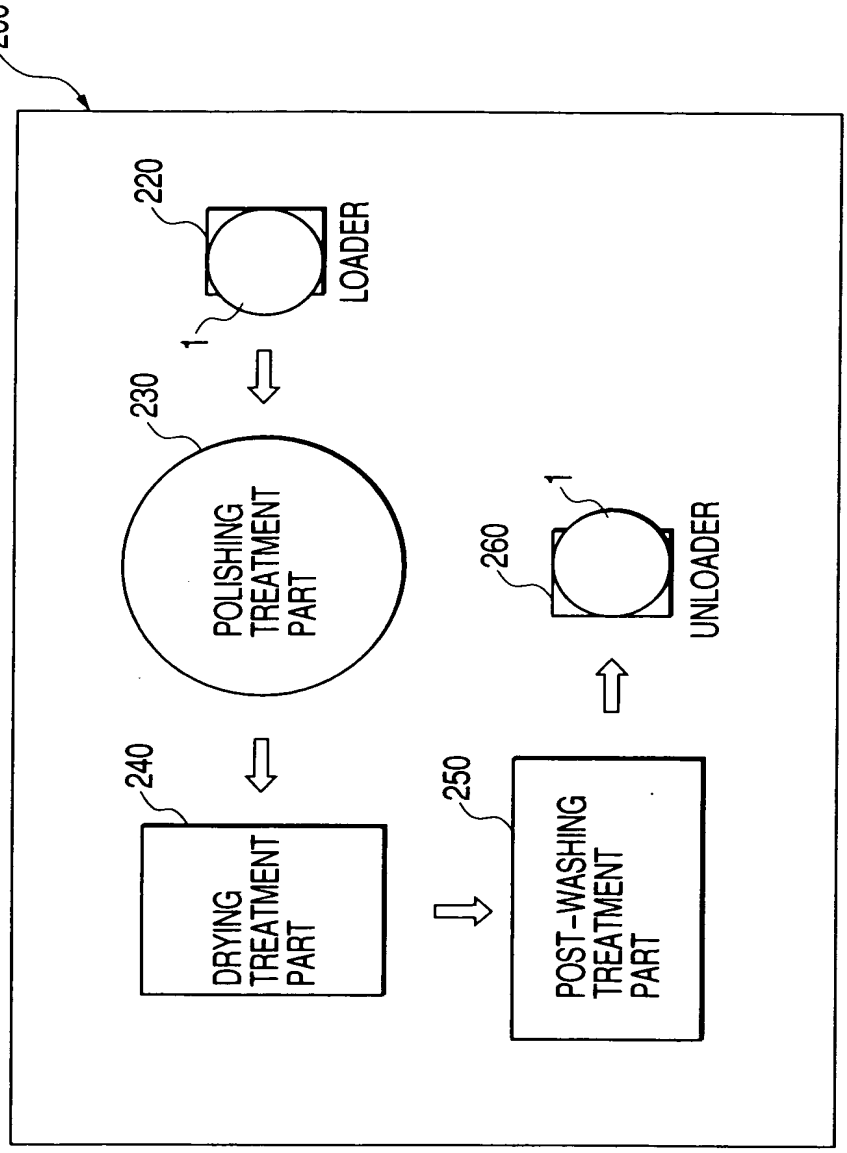

200
220
LOADER
1
230
POLISHING TREATMENT PART
260
1
UNLOADER
240
DRYING TREATMENT PART
250
POST-WASHING TREATMENT PART

FIG. 14

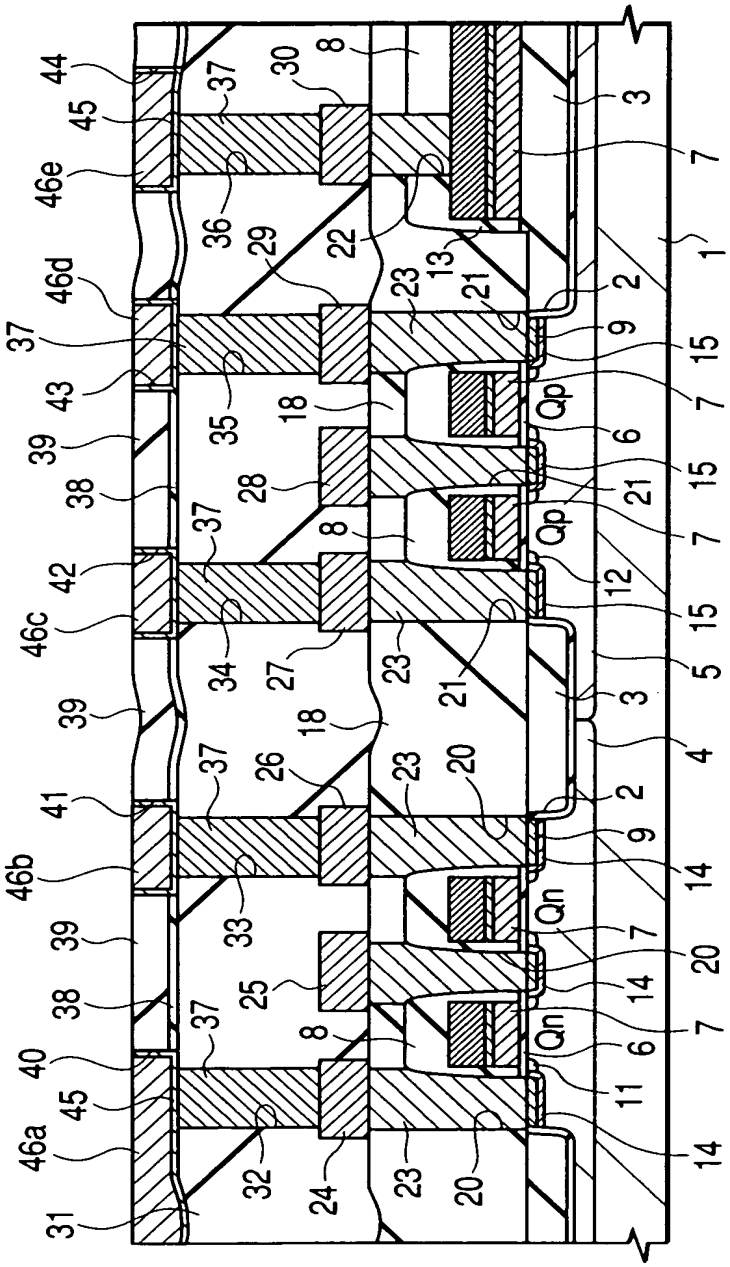

44
45
46e
46d
37
43
39
38
42
46c
39
41
46b
39
38
40
45
46a
31
30
8
37
3
7
36
29
22
13
23
21
2
1
9
15
Qp
7
35
18
6
28
21
15
Qp
8
7
12
34
27
23
21
15
5
3
18
4
26
23
20
2
9
14
Qn
33
7
20
25
14
Qn
8
7
6
11
14
32
24
23
20

FIG. 15(b)

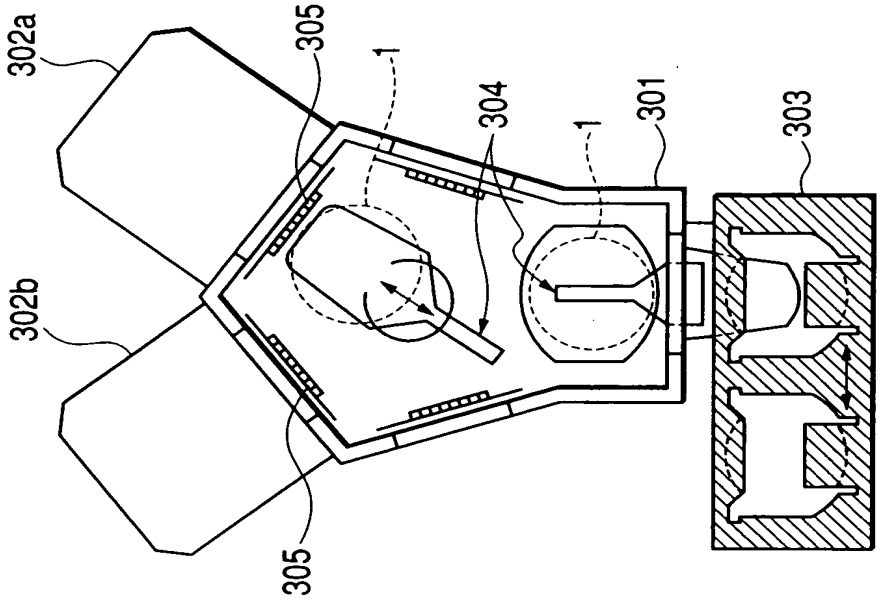


FIG. 15(a)

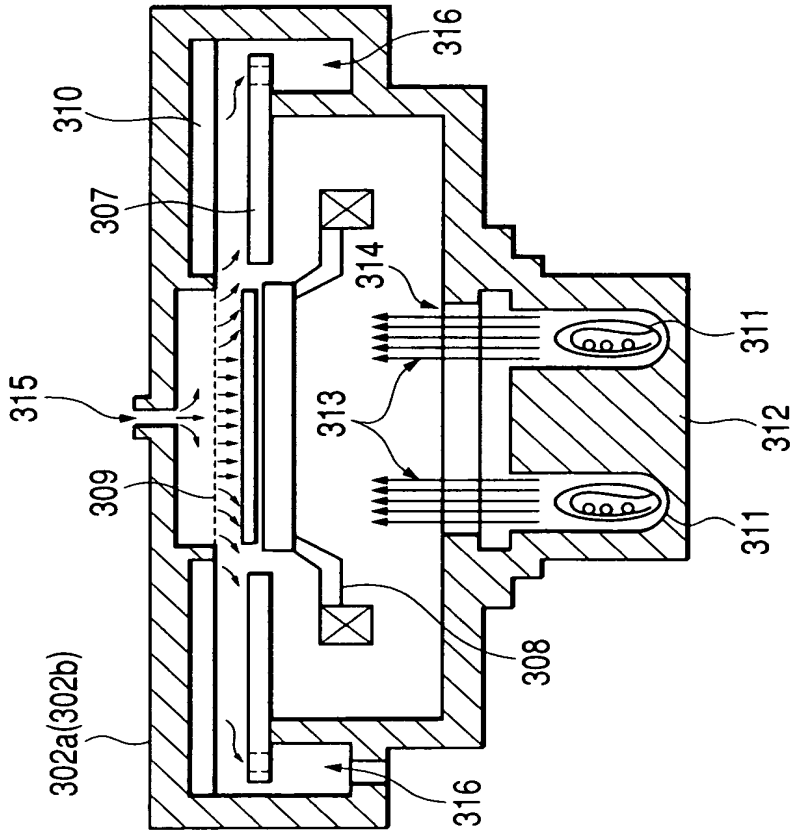


FIG. 16

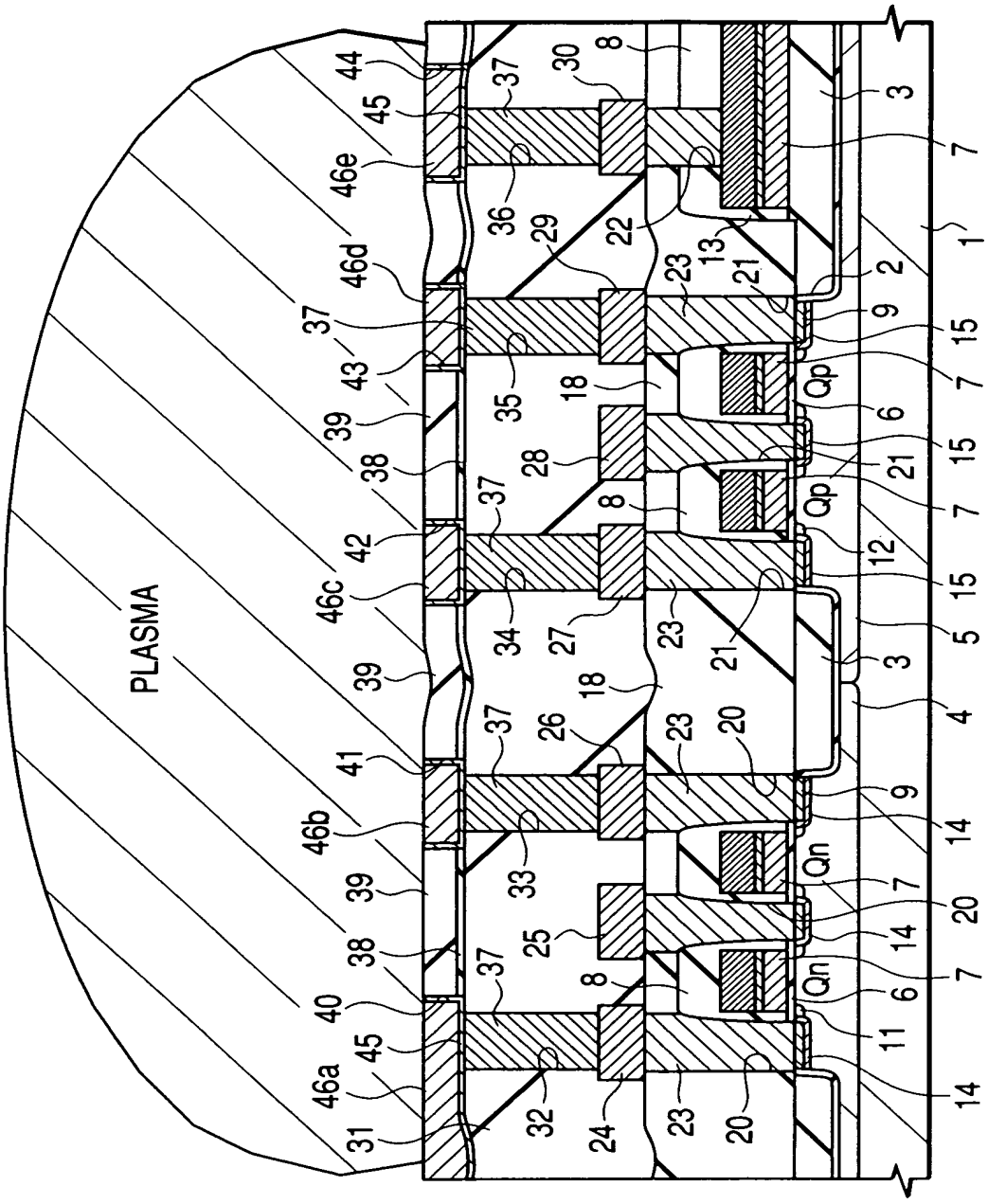


FIG. 17

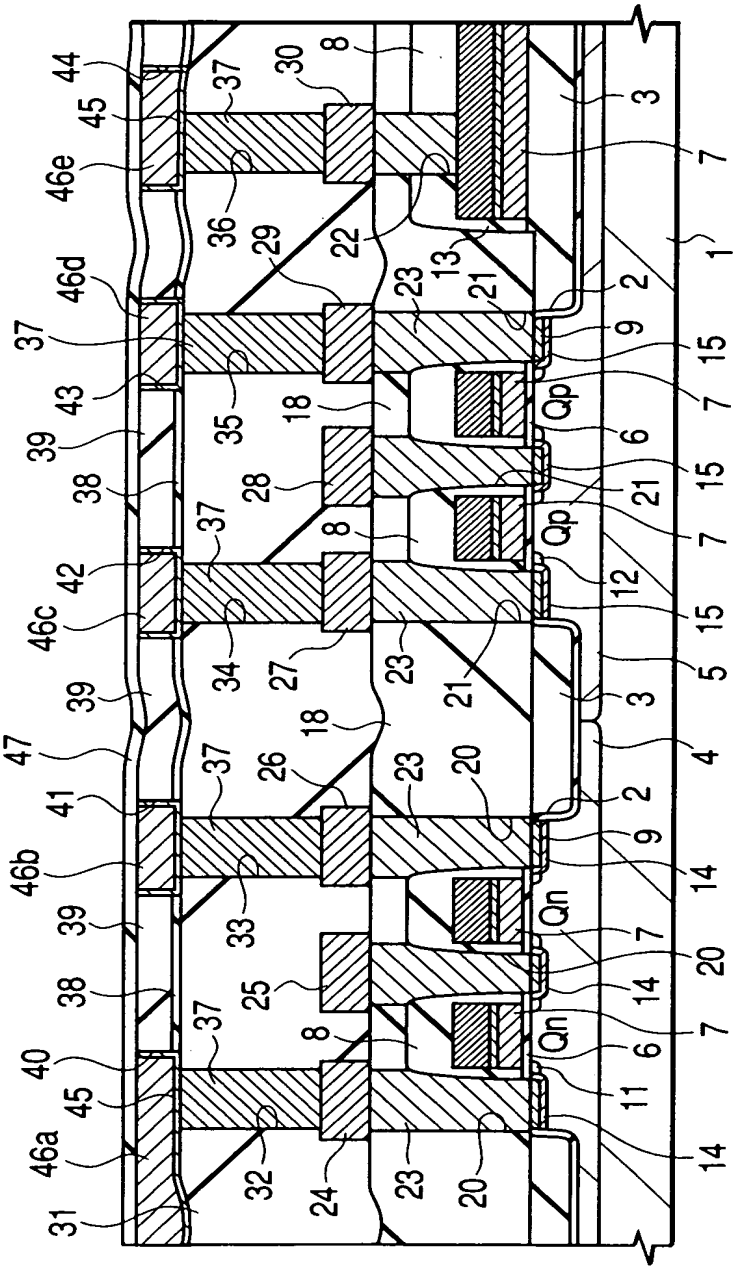


FIG. 18

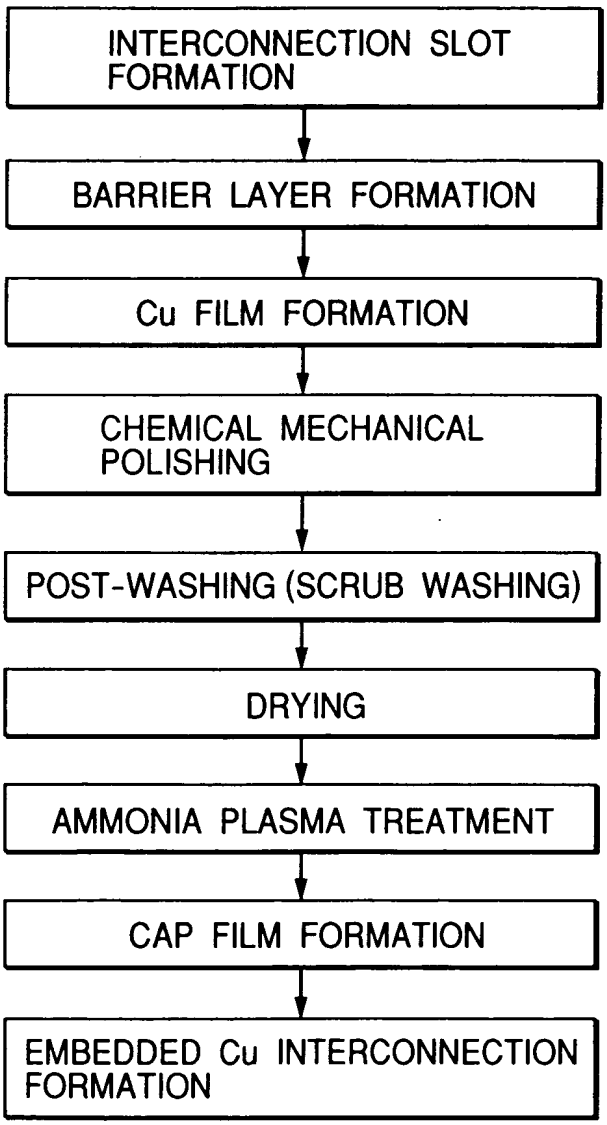

INTERCONNECTION SLOT FORMATION
BARRIER LAYER FORMATION
Cu FILM FORMATION
CHEMICAL MECHANICAL POLISHING
POST-WASHING (SCRUB WASHING)
DRYING
AMMONIA PLASMA TREATMENT
CAP FILM FORMATION
EMBEDDED Cu INTERCONNECTION FORMATION

FIG. 19

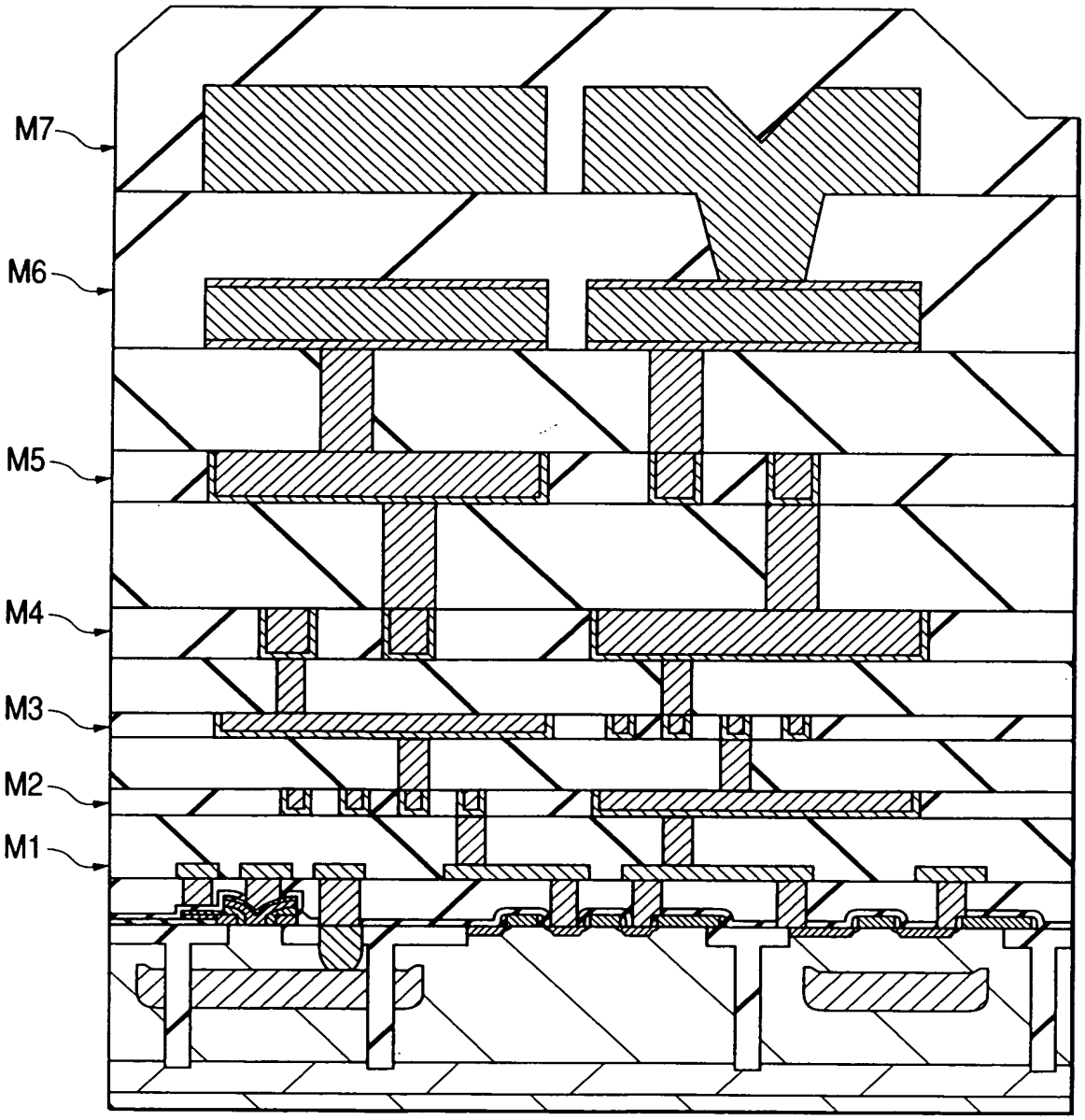


FIG. 20

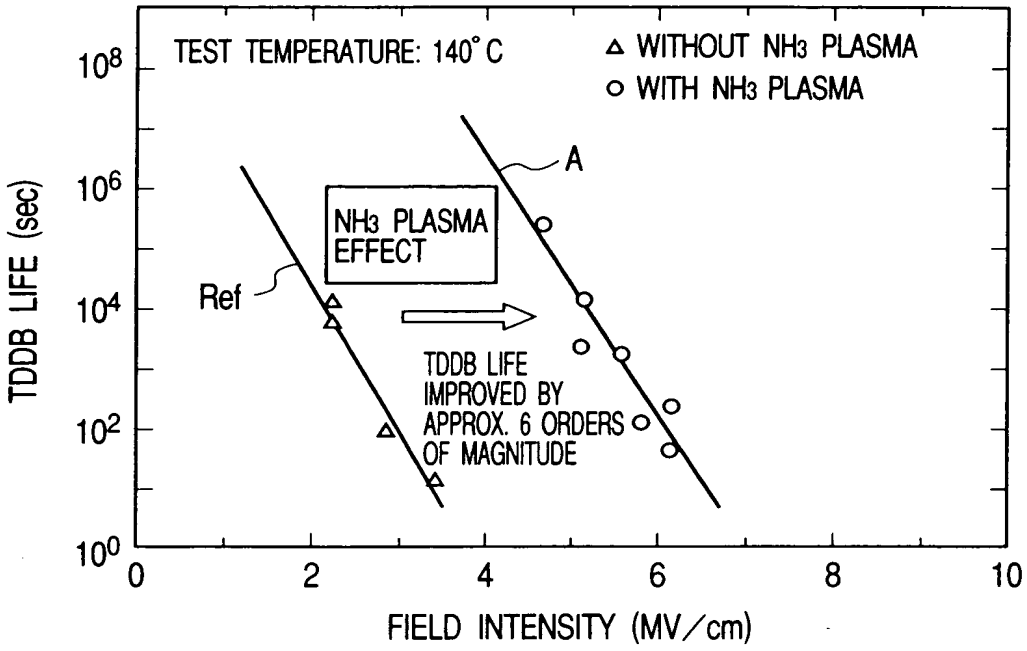

TEST TEMPERATURE: 140°C
△ WITHOUT NH3 PLASMA
○ WITH NH3 PLASMA
A
NH3 PLASMA EFFECT
Ref
TDDB LIFE IMPROVED BY APPROX. 6 ORDERS OF MAGNITUDE
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)

FIG. 21

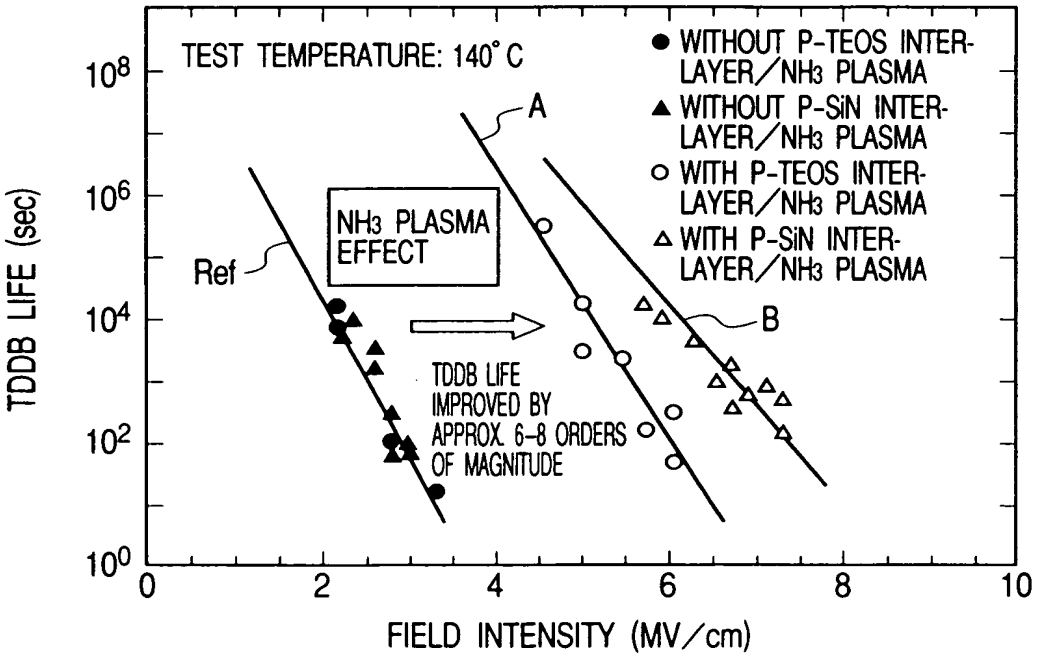

TEST TEMPERATURE: 140°C
● WITHOUT P-TEOS INTER-LAYER/NH3 PLASMA
▲ WITHOUT P-SiN INTER-LAYER/NH3 PLASMA
○ WITH P-TEOS INTER-LAYER/NH3 PLASMA
△ WITH P-SiN INTER-LAYER/NH3 PLASMA
A
B
NH3 PLASMA EFFECT
Ref
TDDB LIFE IMPROVED BY APPROX. 6-8 ORDERS OF MAGNITUDE
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)

FIG. 22(a)

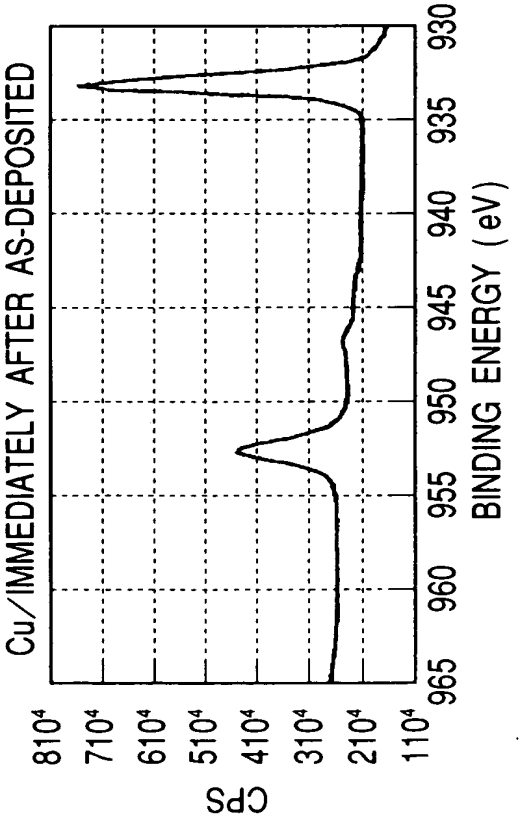


FIG. 22(b)

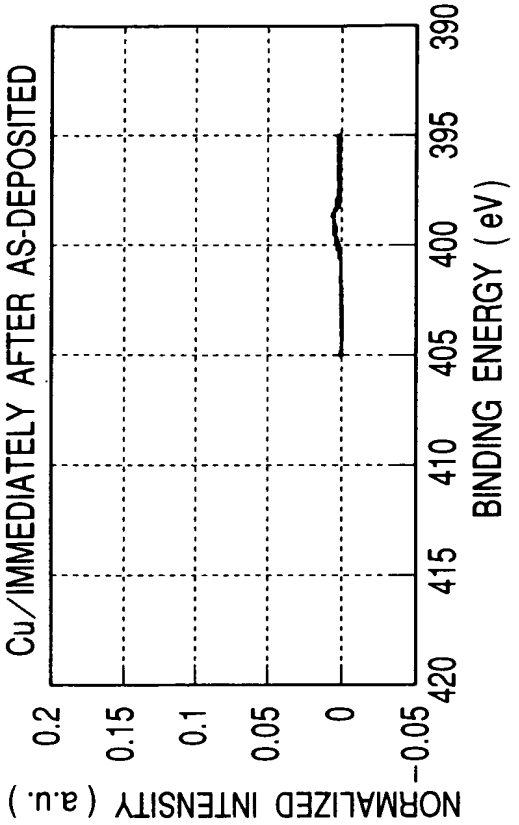


FIG. 22(c)

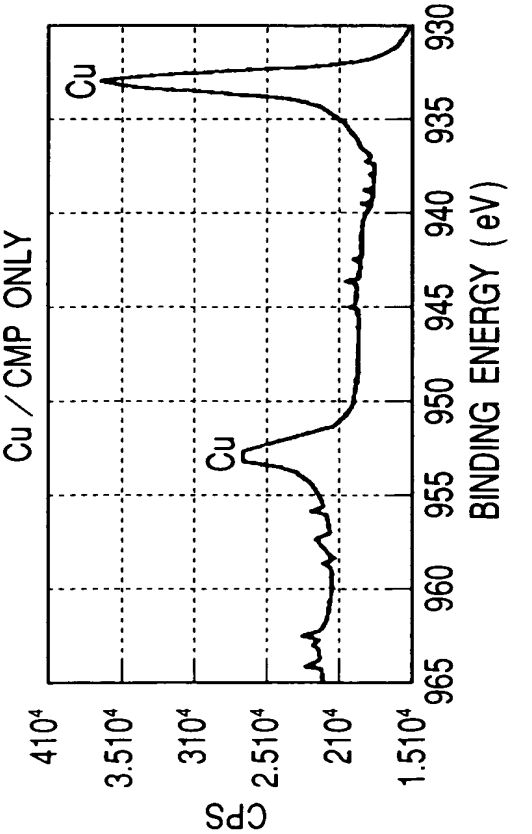


FIG. 22(d)

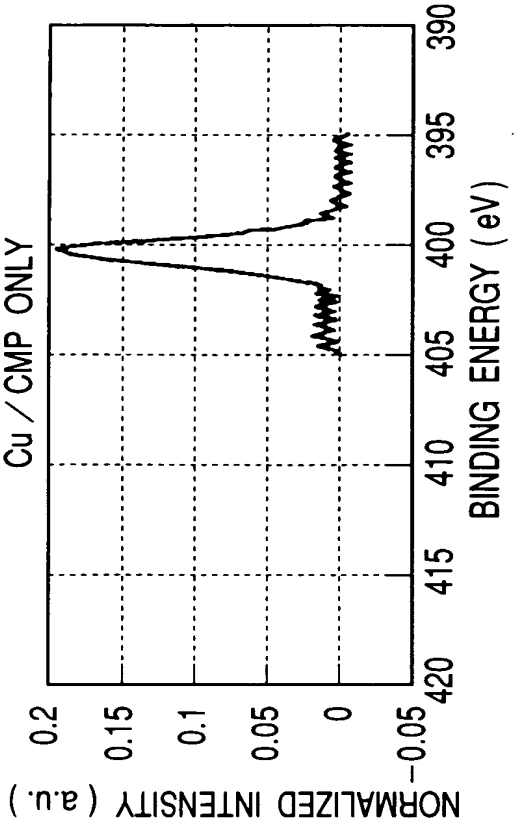


FIG. 23(a)

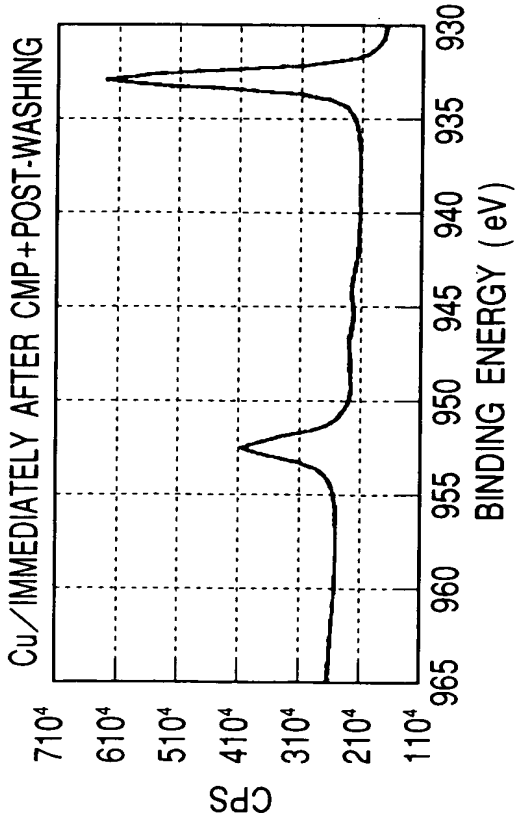


FIG. 23(b)

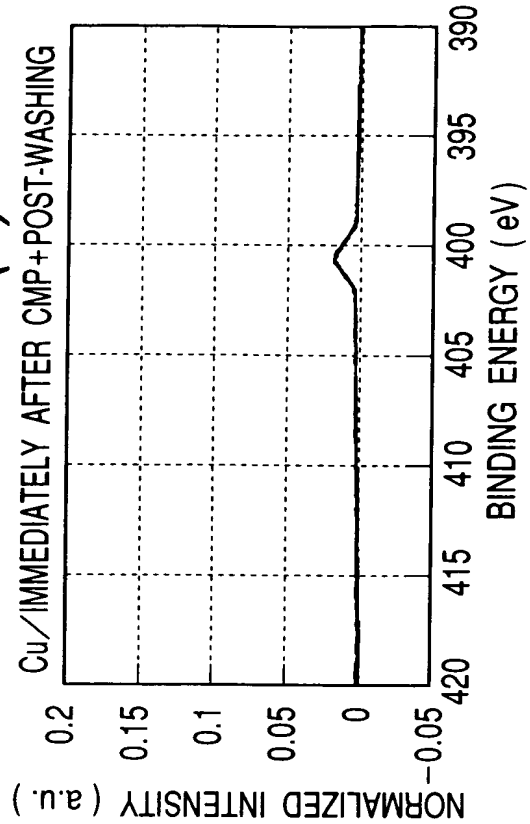


FIG. 23(c)

FIG. 23(d)

FIG. 24(a)

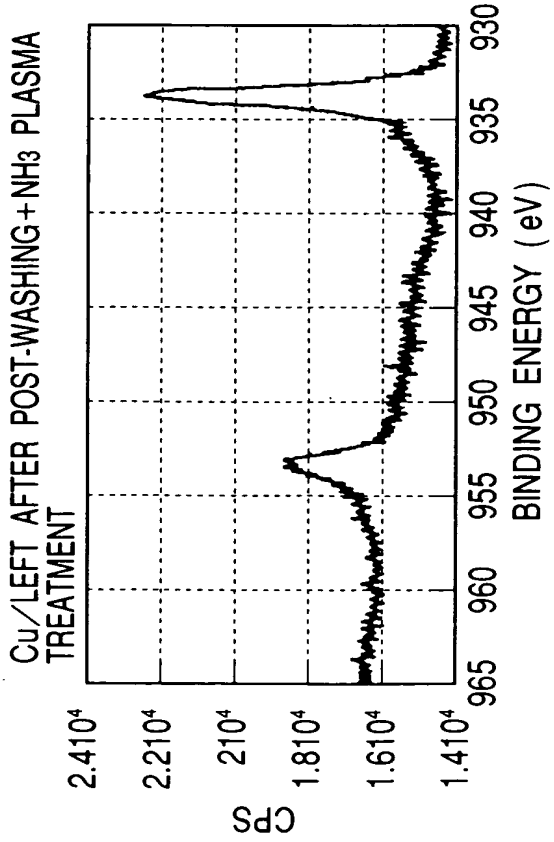


FIG. 24(b)

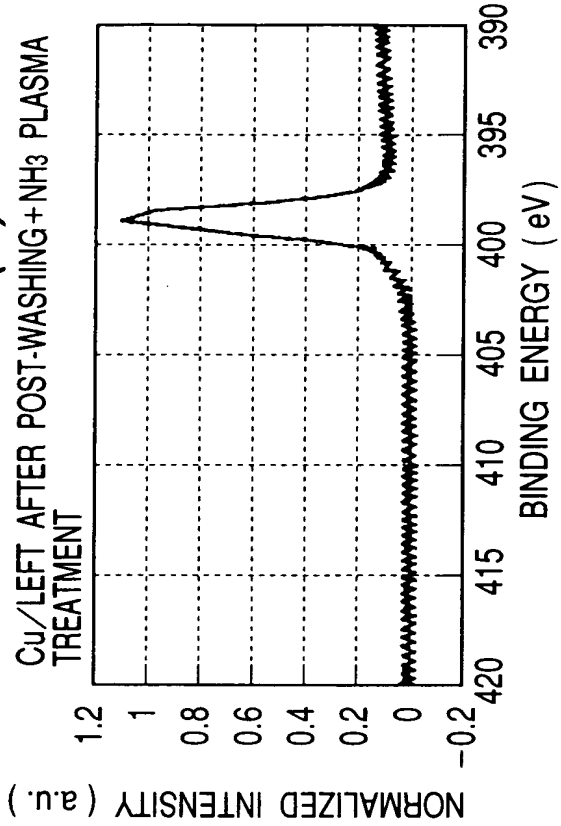


FIG. 24(c)

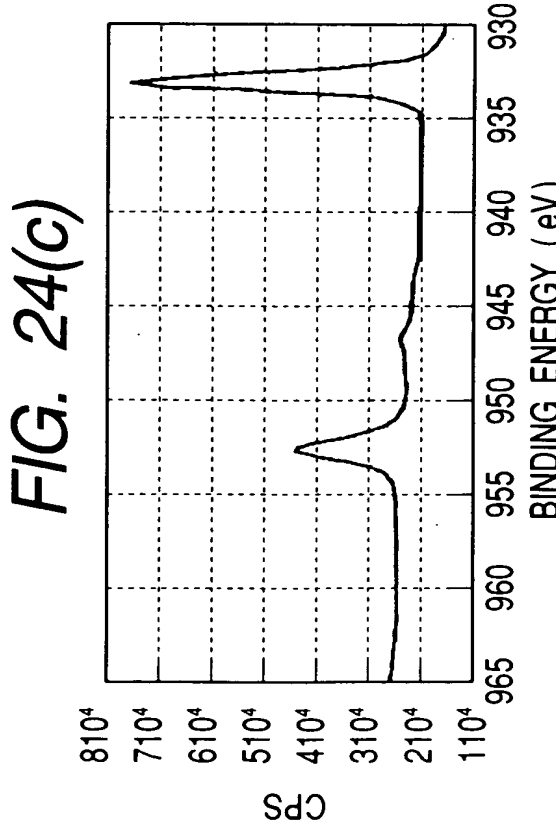


FIG. 24(d)

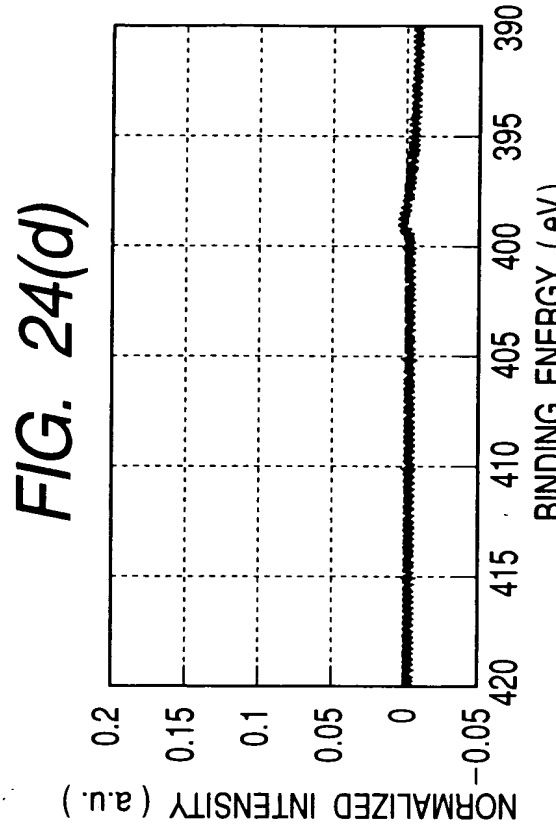


FIG. 25(a)

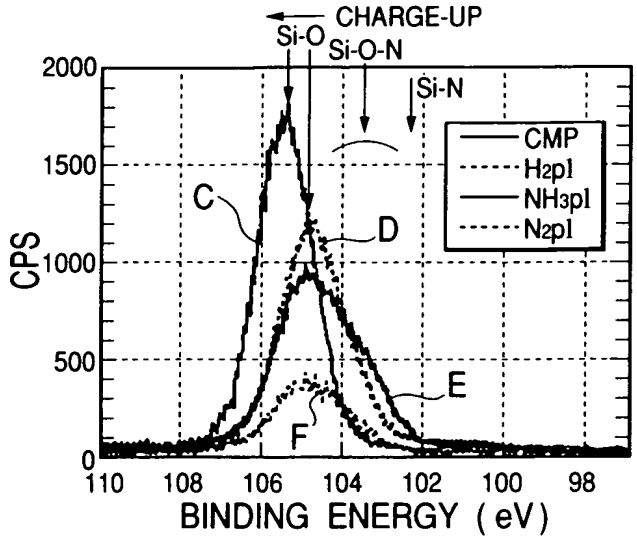


FIG. 25(b)

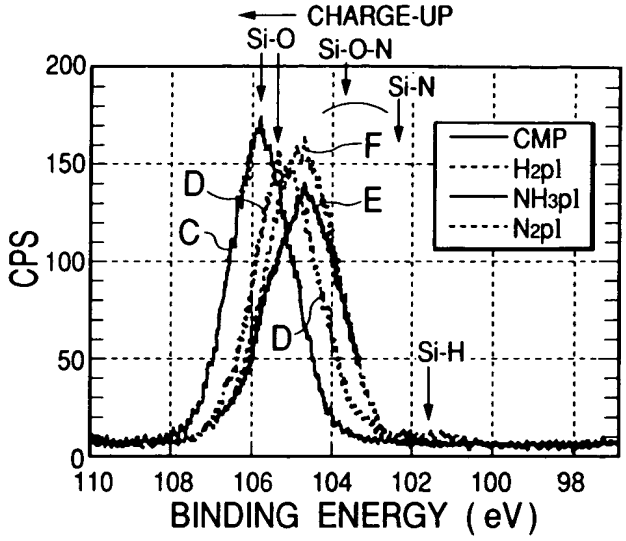


FIG. 25(c)

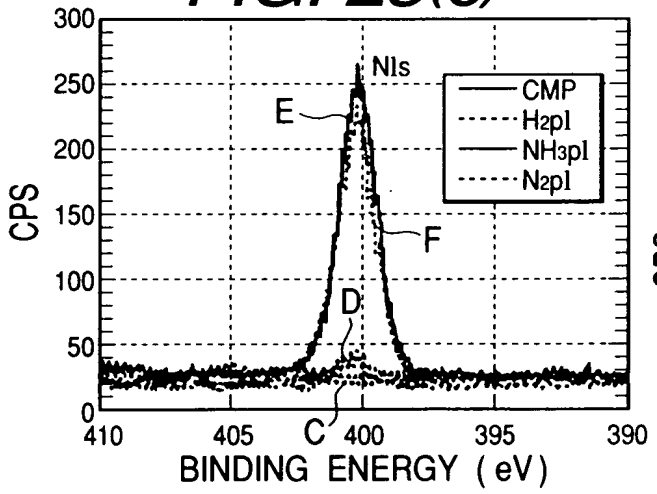


FIG. 25(d)

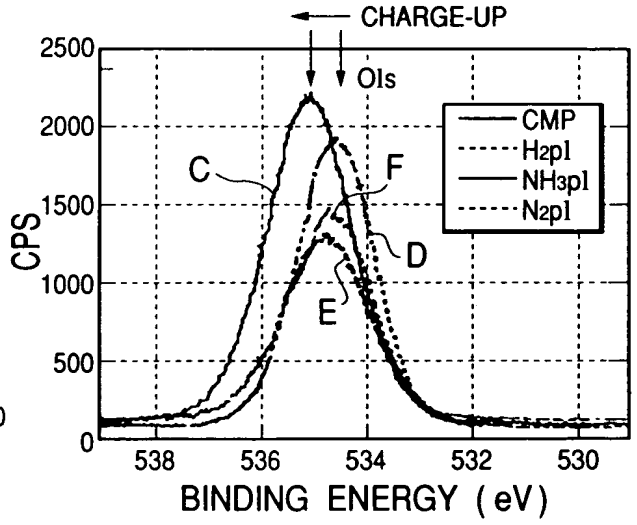


FIG. 25(e)

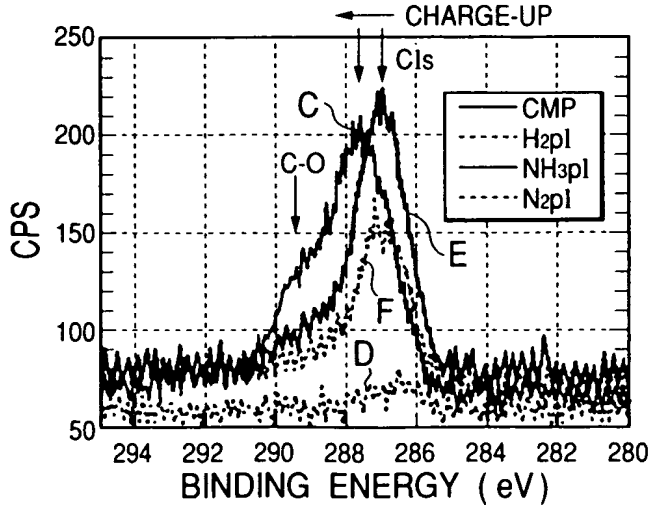
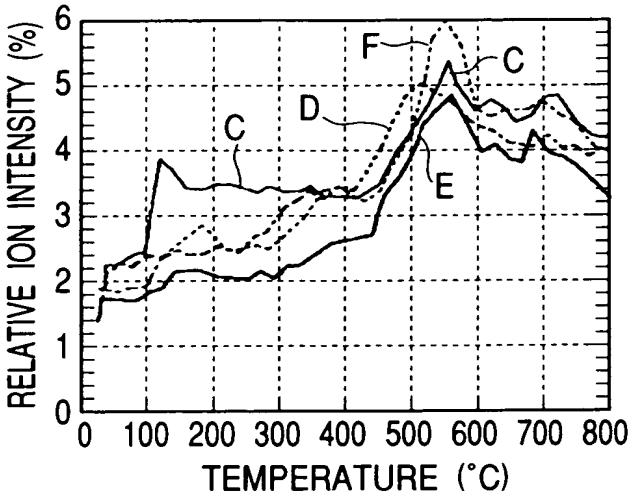


FIG. 25(f)

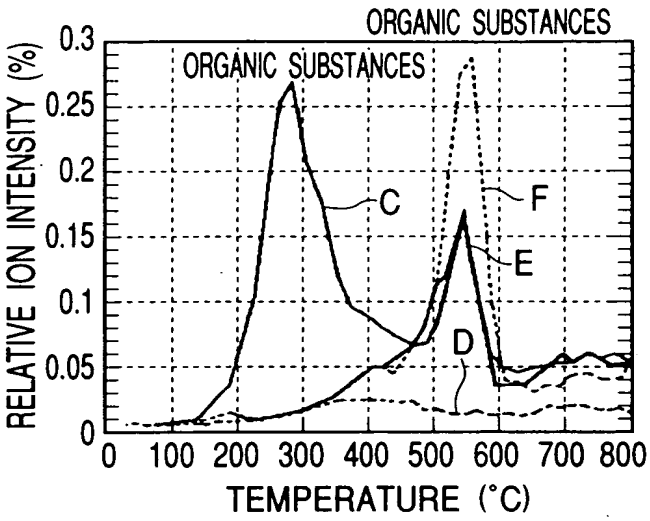
CONDITION	Si3Nx
CMP	—
H2pl	Si3N1.08
NH3pl	Si3N4.22
N2pl	Si3N3.81

FIG. 26(a)



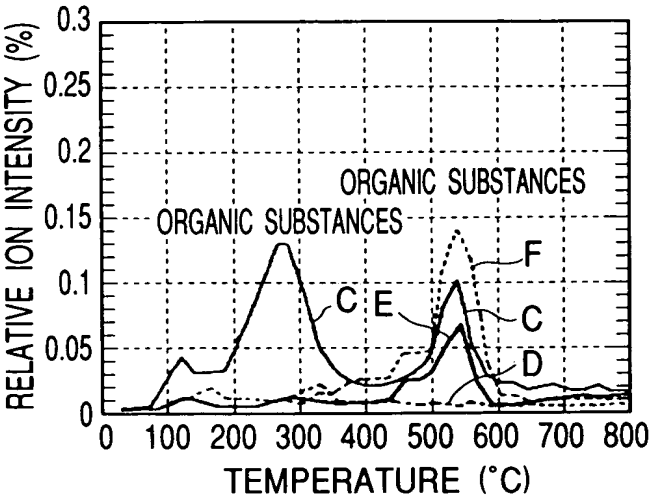
THERMAL DISSOCIATION OF HYDROGEN, Ar−H m/z=41

FIG. 26(b)



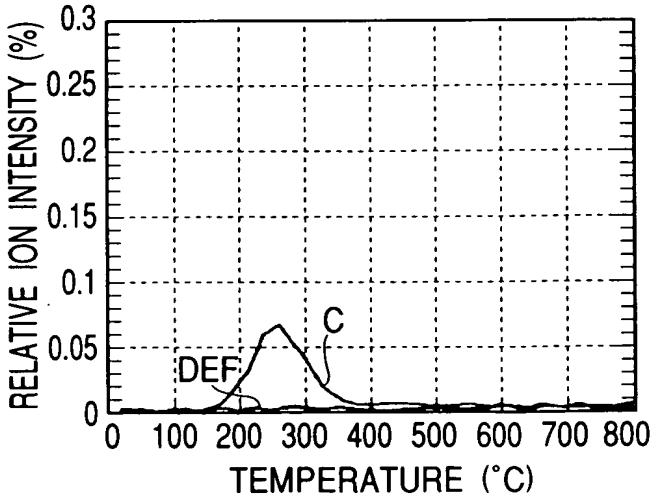
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, A(CnH2n−1) C2H3 m/z=27

FIG. 26(c)



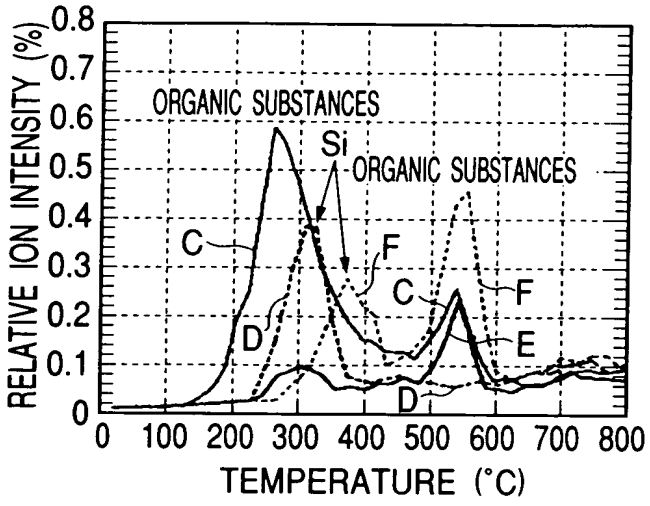
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, B(CnH2n+1) C4H9 m/z=57

FIG. 26(d)



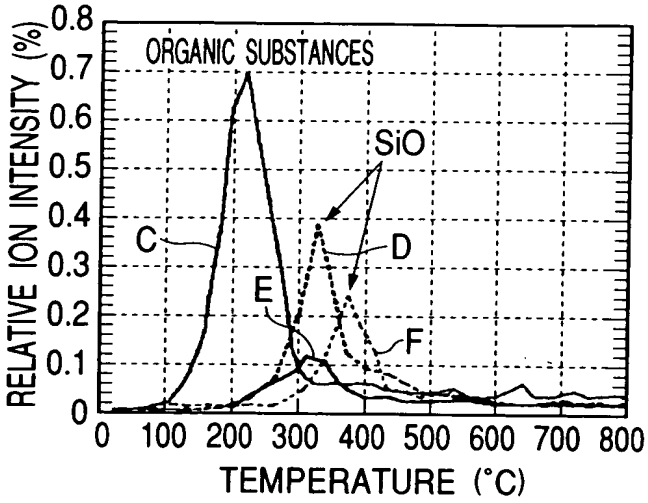
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, C(CnH2n+1O) C3H7O m/z=59

FIG. 27(a)



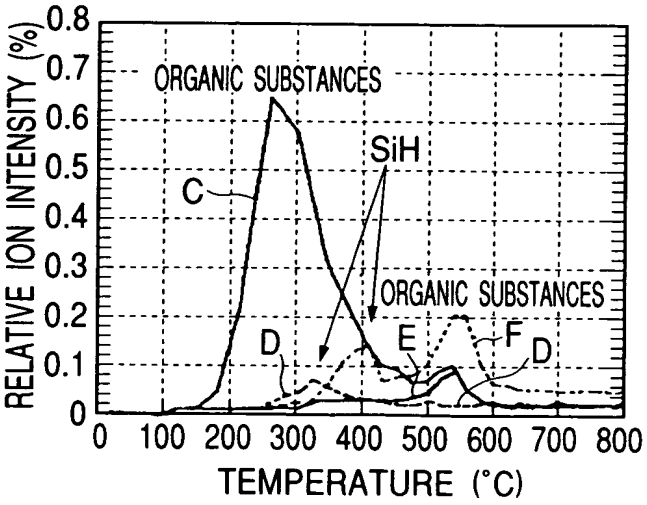
THERMAL DISSOCIATION OF Si AND ORGANIC SUBSTANCES
Si, C2H4 m/z=28

FIG. 27(b)



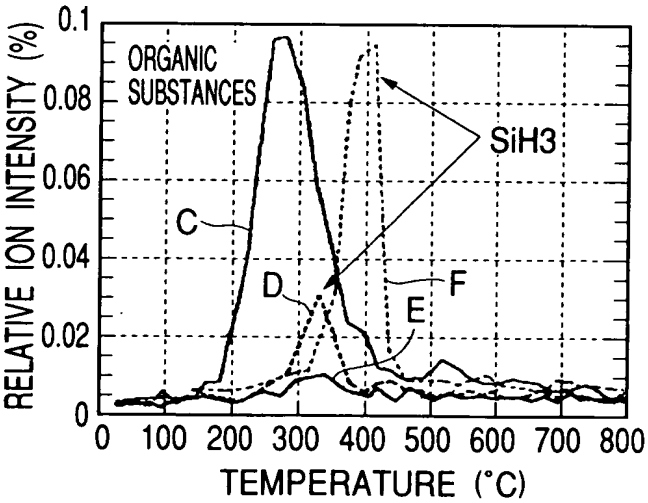
THERMAL DISSOCIATION OF SiO AND ORGANIC SUBSTANCES
SiO, C3H6 m/z=44

FIG. 27(c)



THERMAL DISSOCIATION OF SiH AND ORGANIC SUBSTANCES
SiH, C2H5 m/z=29

FIG. 27(d)



THERMAL DISSOCIATION OF SiH3 AND ORGANIC SUBSTANCES
SiH3 m/z=31

FIG. 28

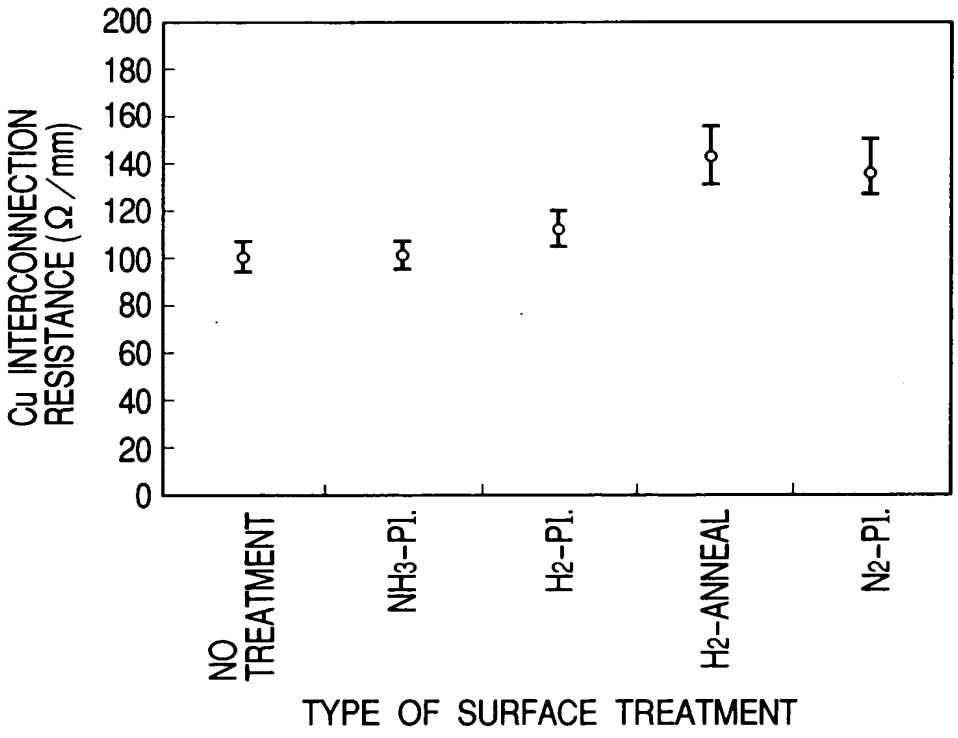

Cu INTERCONNECTION RESISTANCE (Ω/mm)
200
180
160
140
120
100
80
60
40
20
0
NO TREATMENT
NH3-Pl.
H2-Pl.
H2-ANNEAL
N2-Pl.
TYPE OF SURFACE TREATMENT

FIG. 29

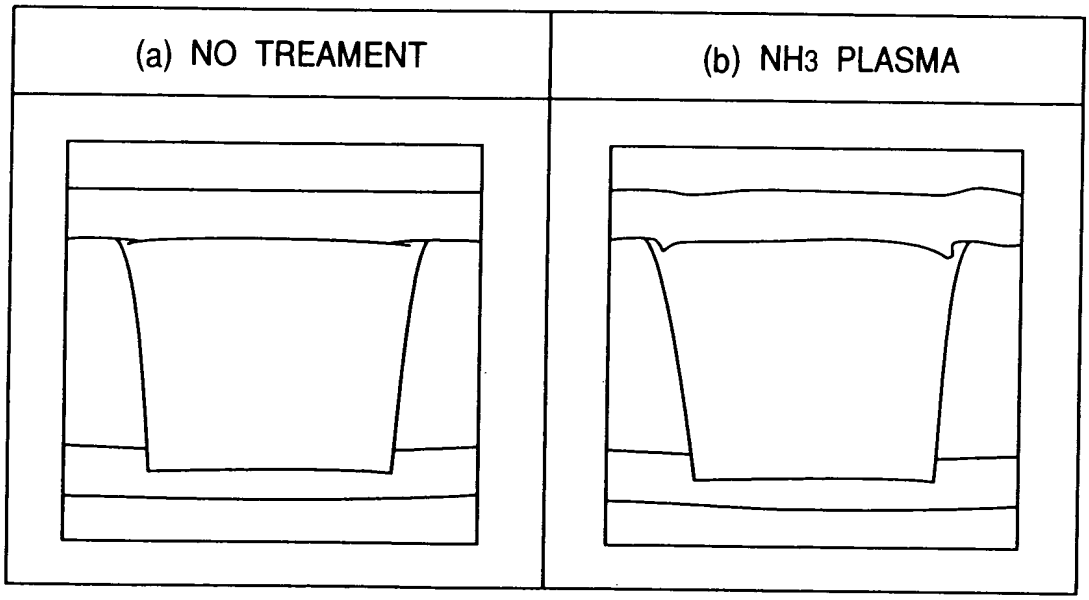


FIG. 30

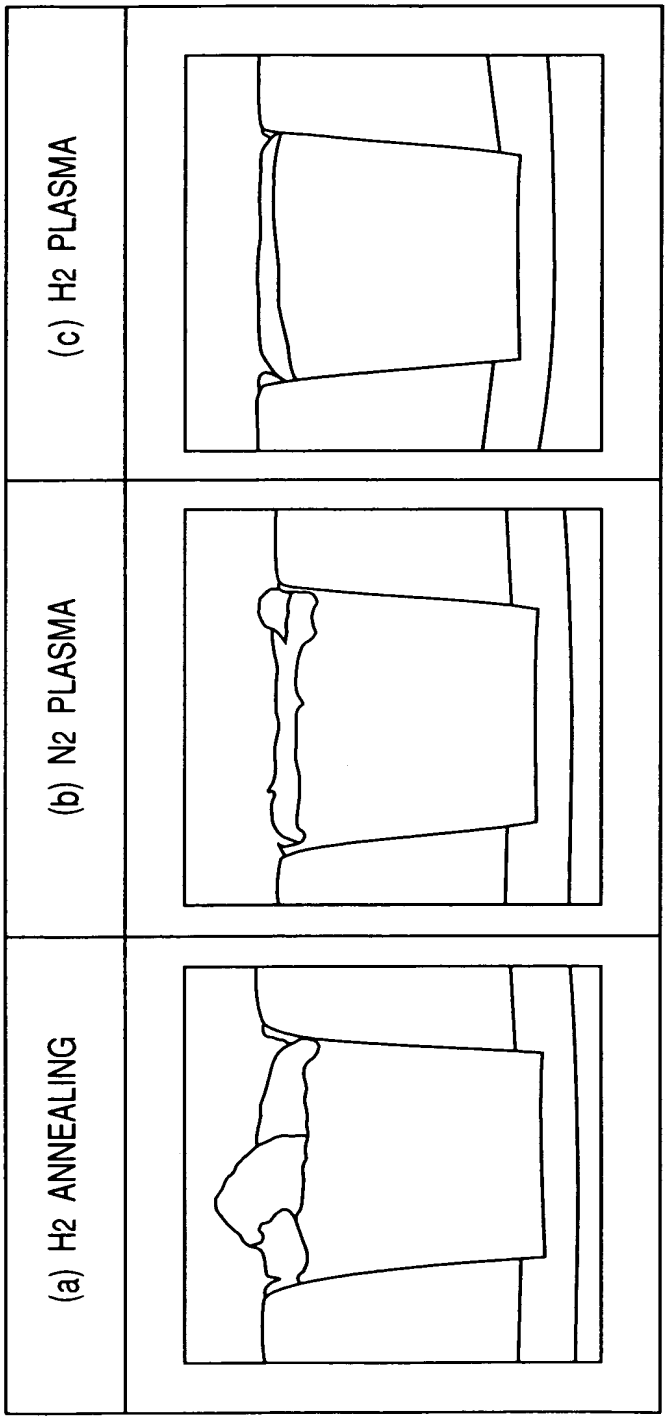


FIG. 31(a)

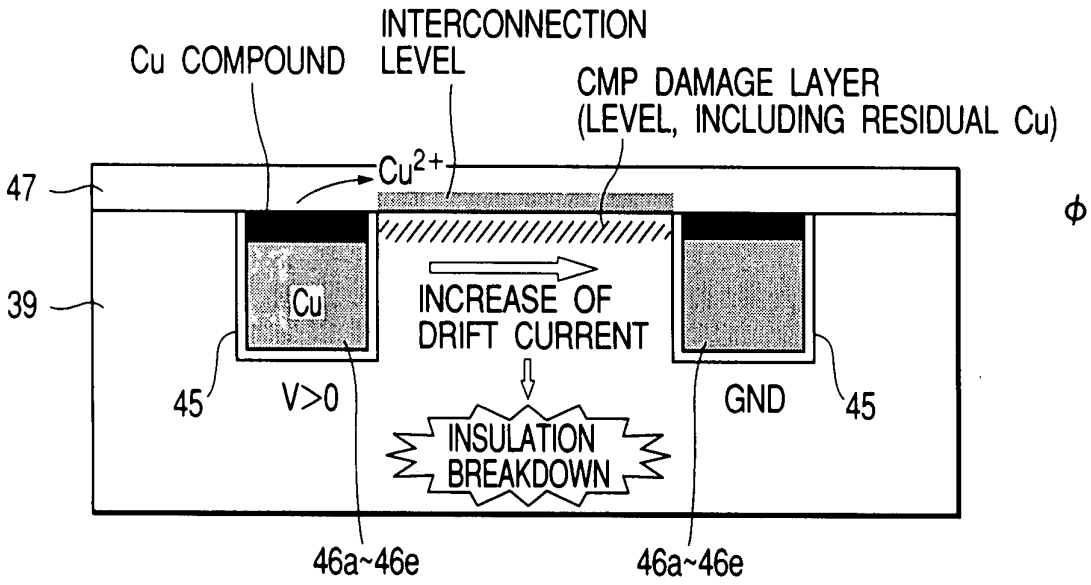


FIG. 31(b)

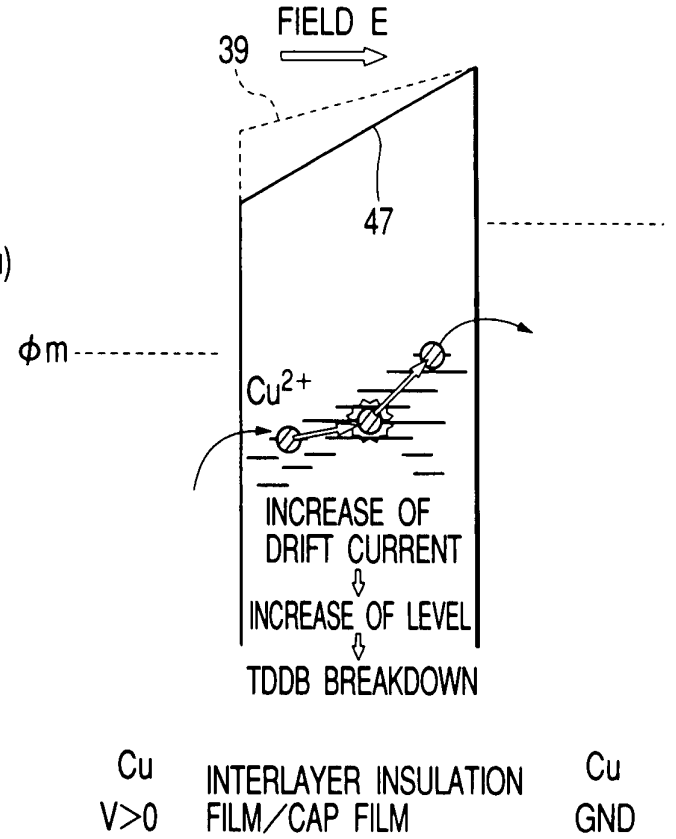


FIG. 32(a)

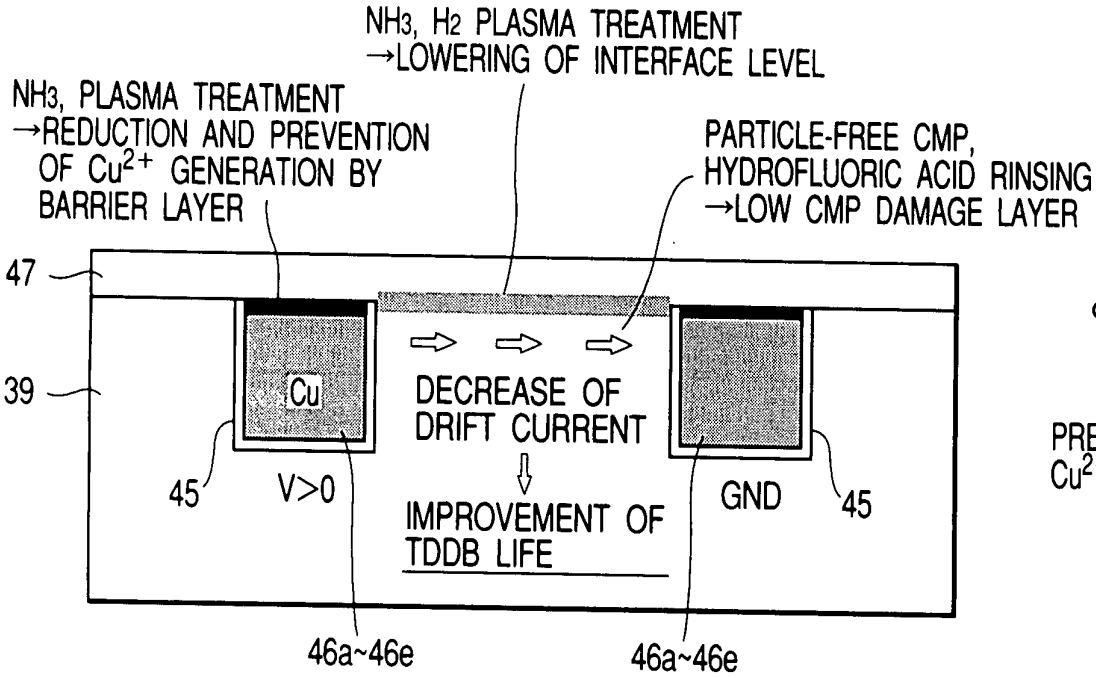


FIG. 32(b)

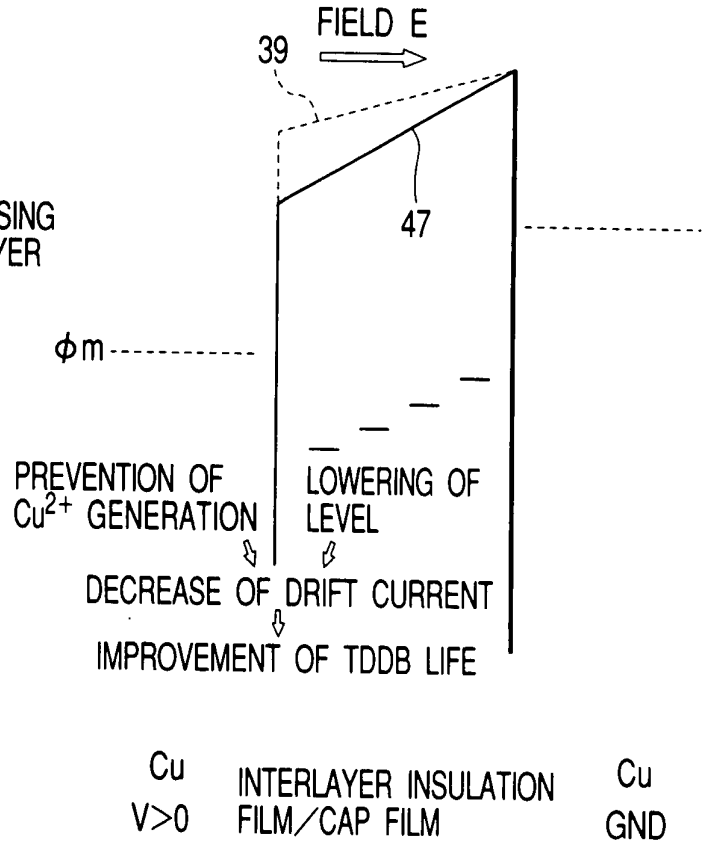


FIG. 33

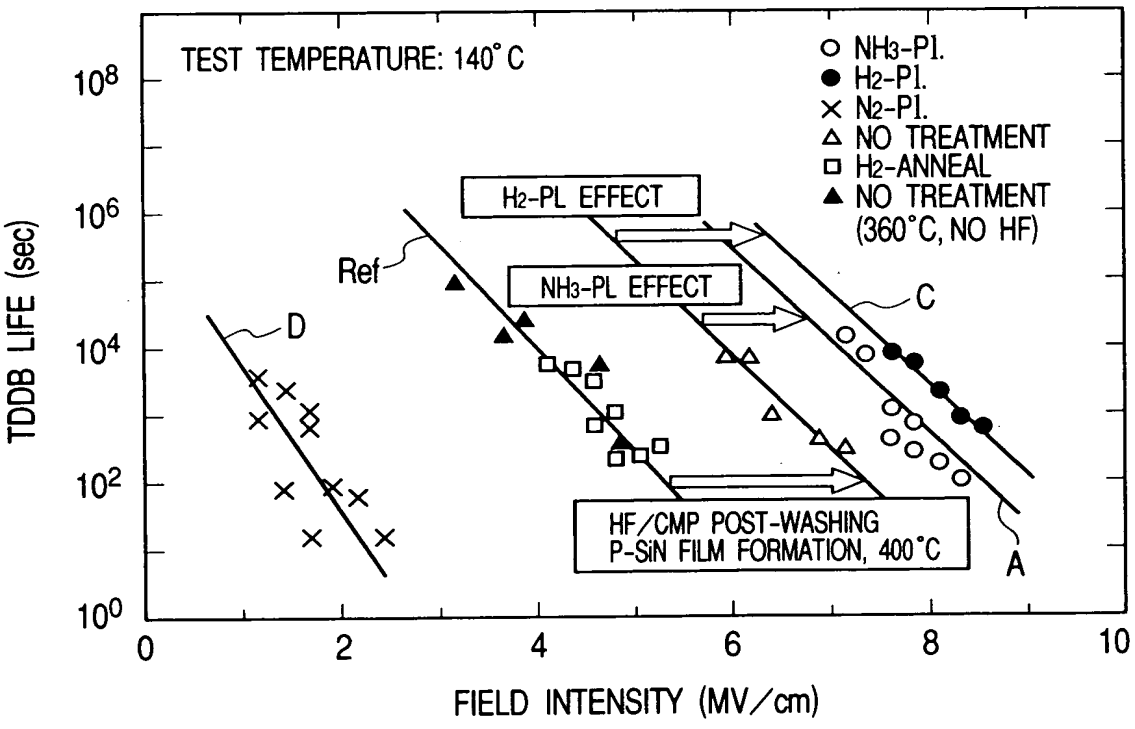

TEST TEMPERATURE: 140°C
NH3-PI.
H2-PI.
N2-PI.
NO TREATMENT
H2-ANNEAL
NO TREATMENT
(360°C, NO HF)
H2-PL EFFECT
NH3-PL EFFECT
Ref
C
D
A
HF/CMP POST-WASHING
P-SiN FILM FORMATION, 400°C
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10

FIG. 34

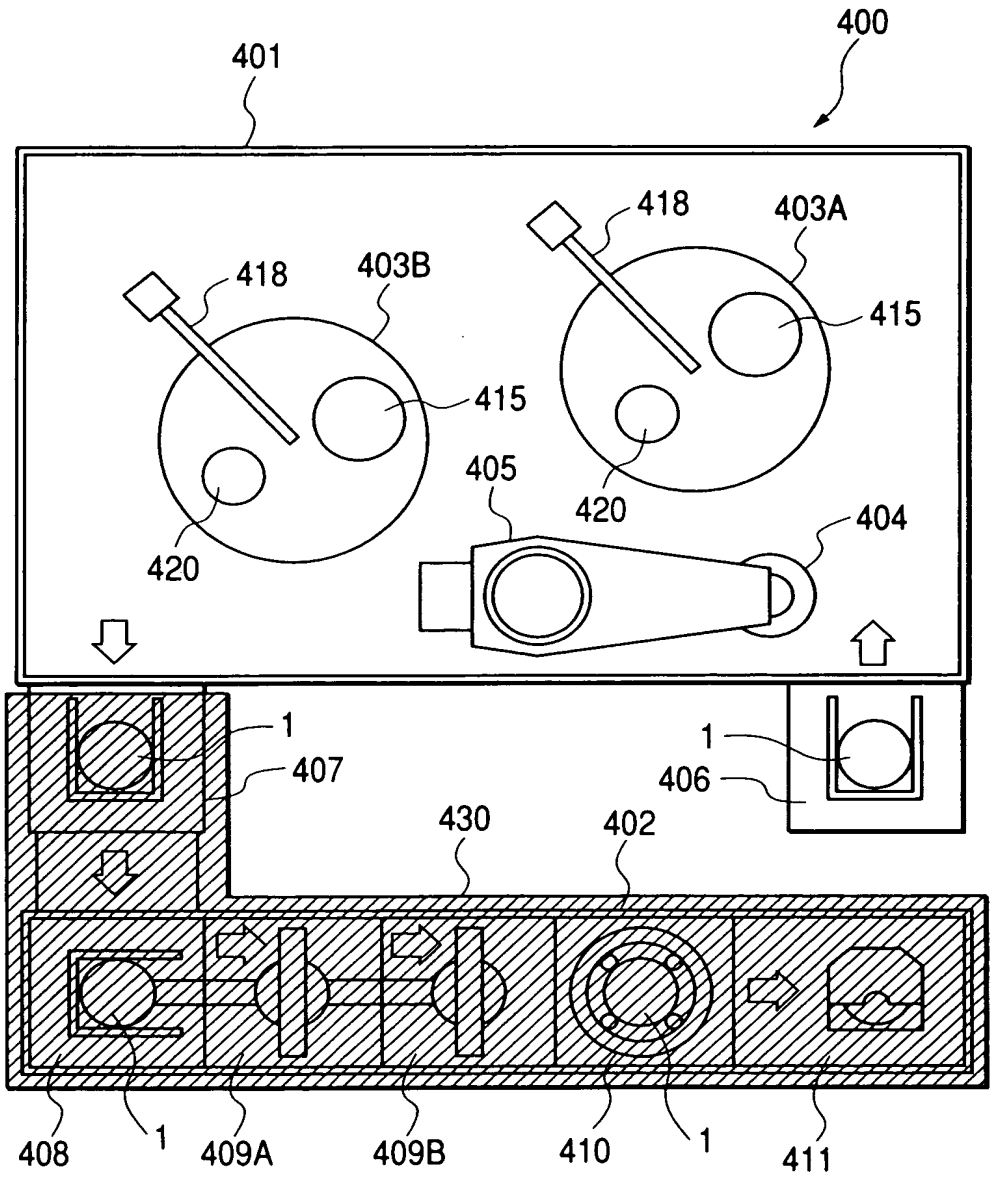

400
401
418
403A
415
418
403B
415
405
420
420
404
1
407
1
406
430
402
408
1
409A
409B
410
1
411

FIG. 35

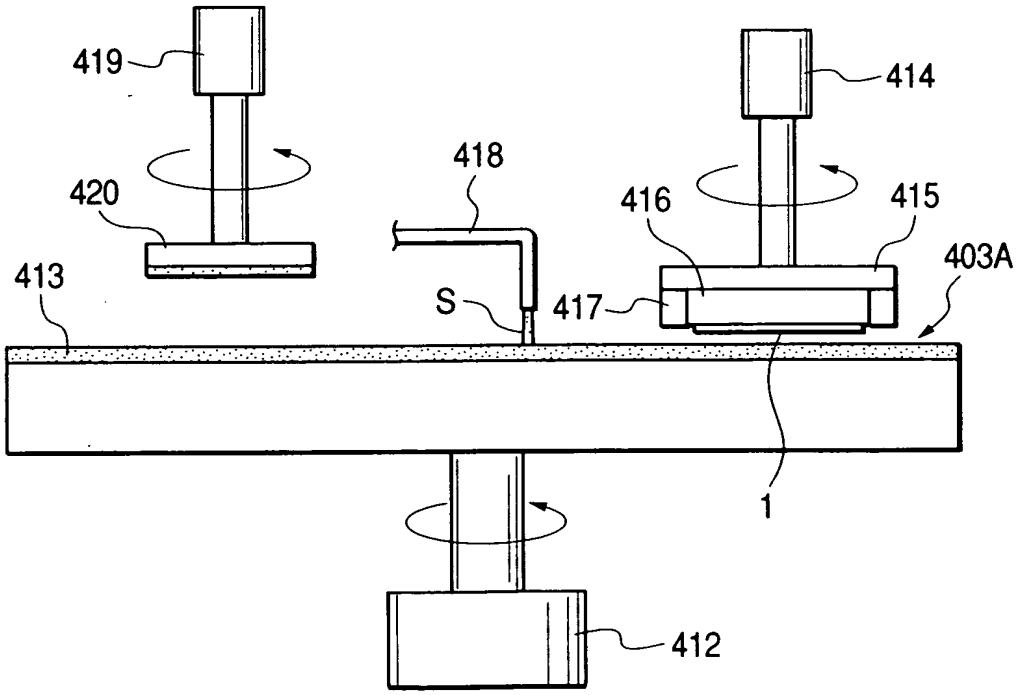


FIG. 36

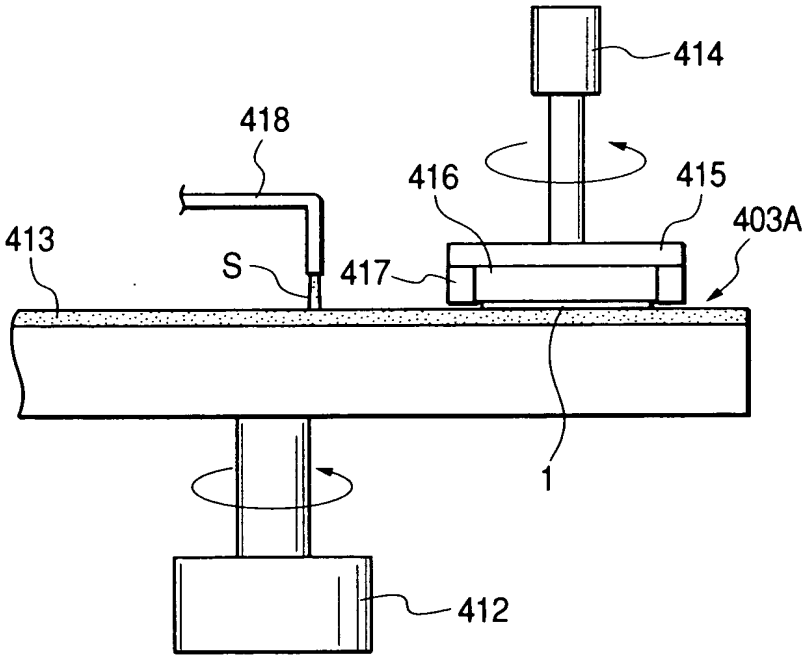


FIG. 37

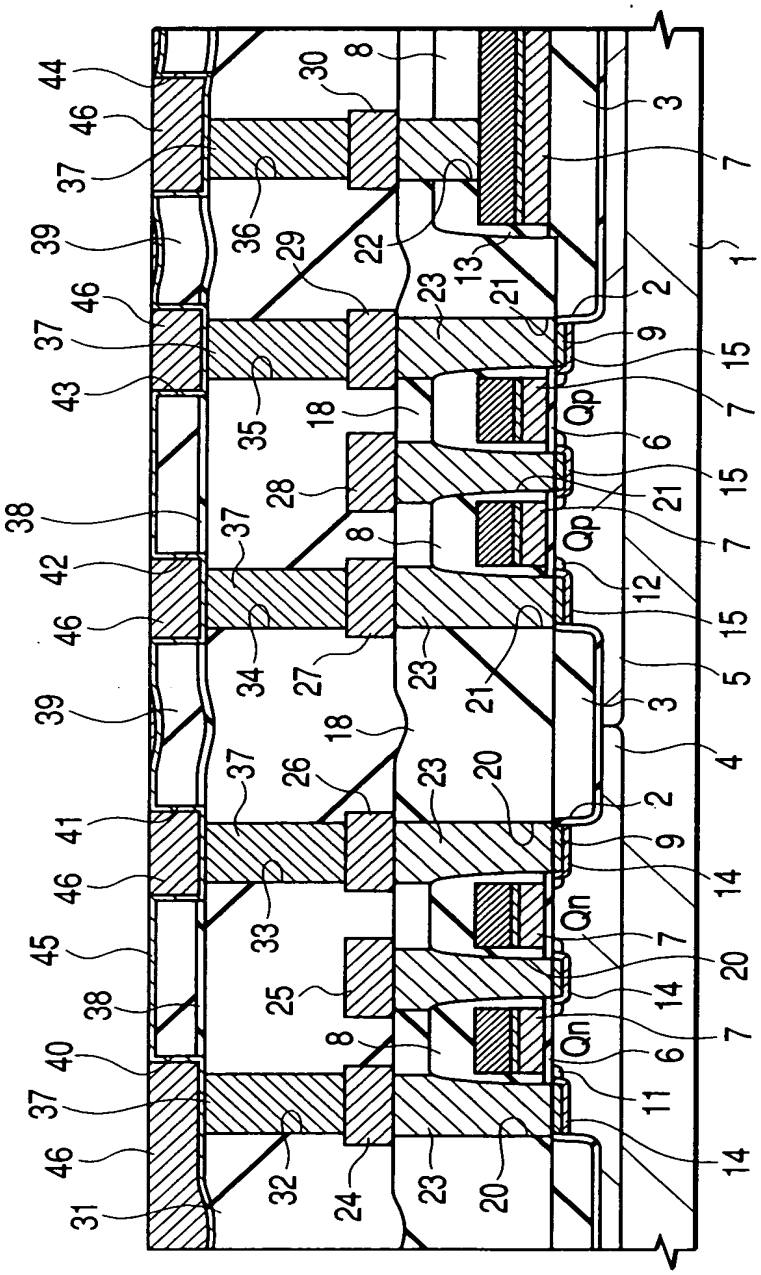


FIG. 38(a)

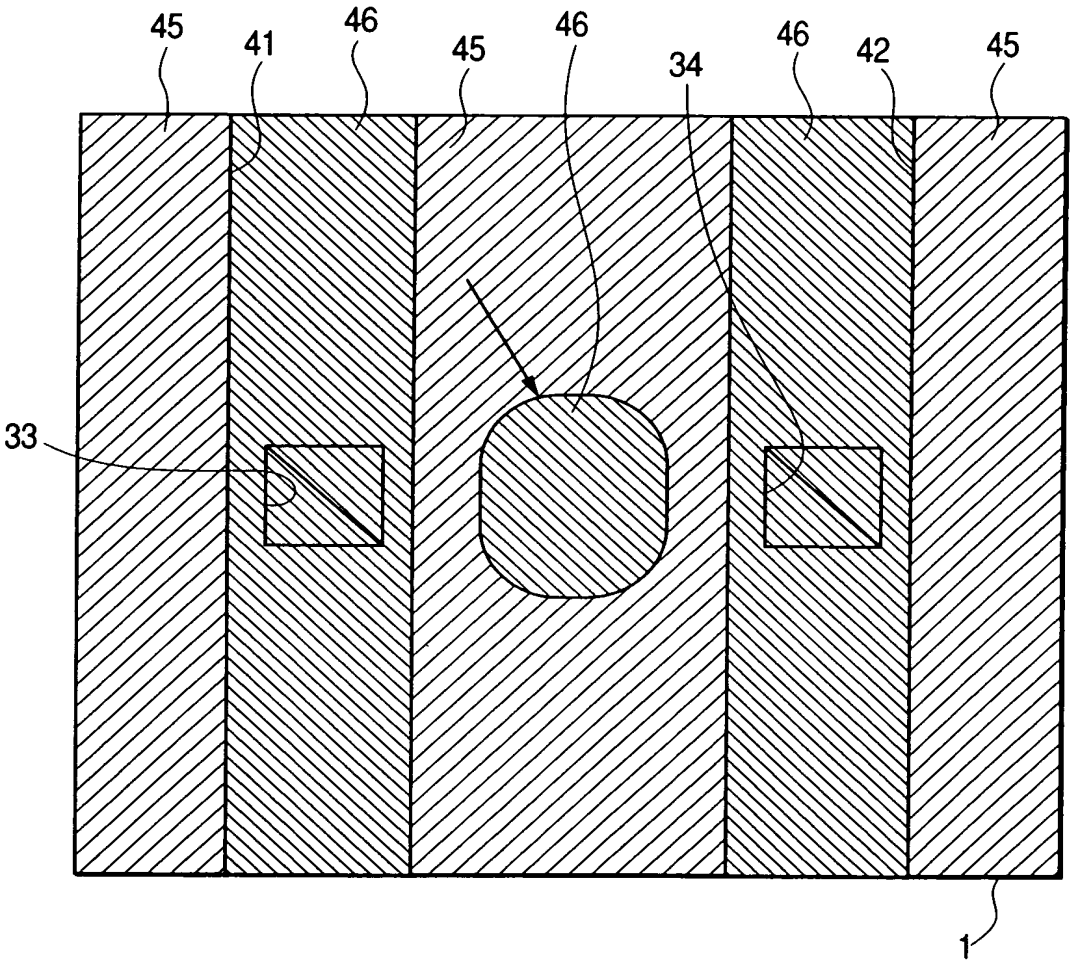


FIG. 38(b)

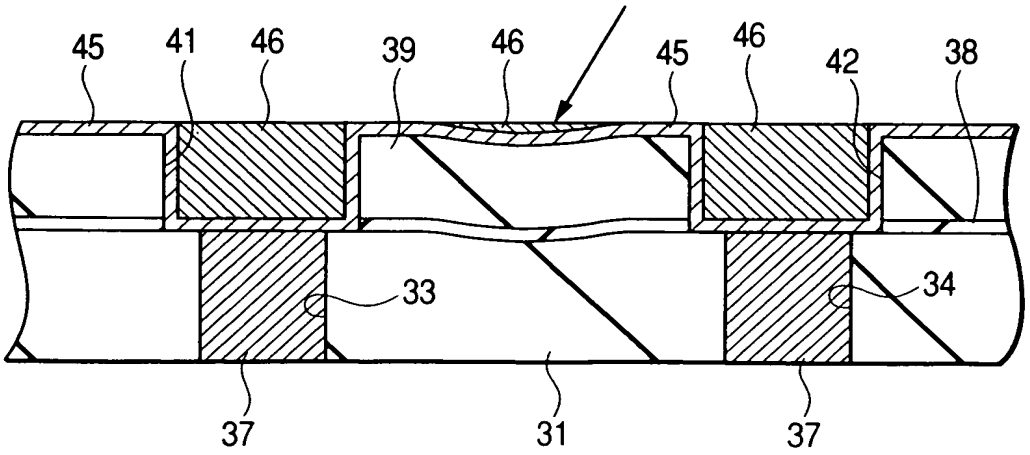


FIG. 39

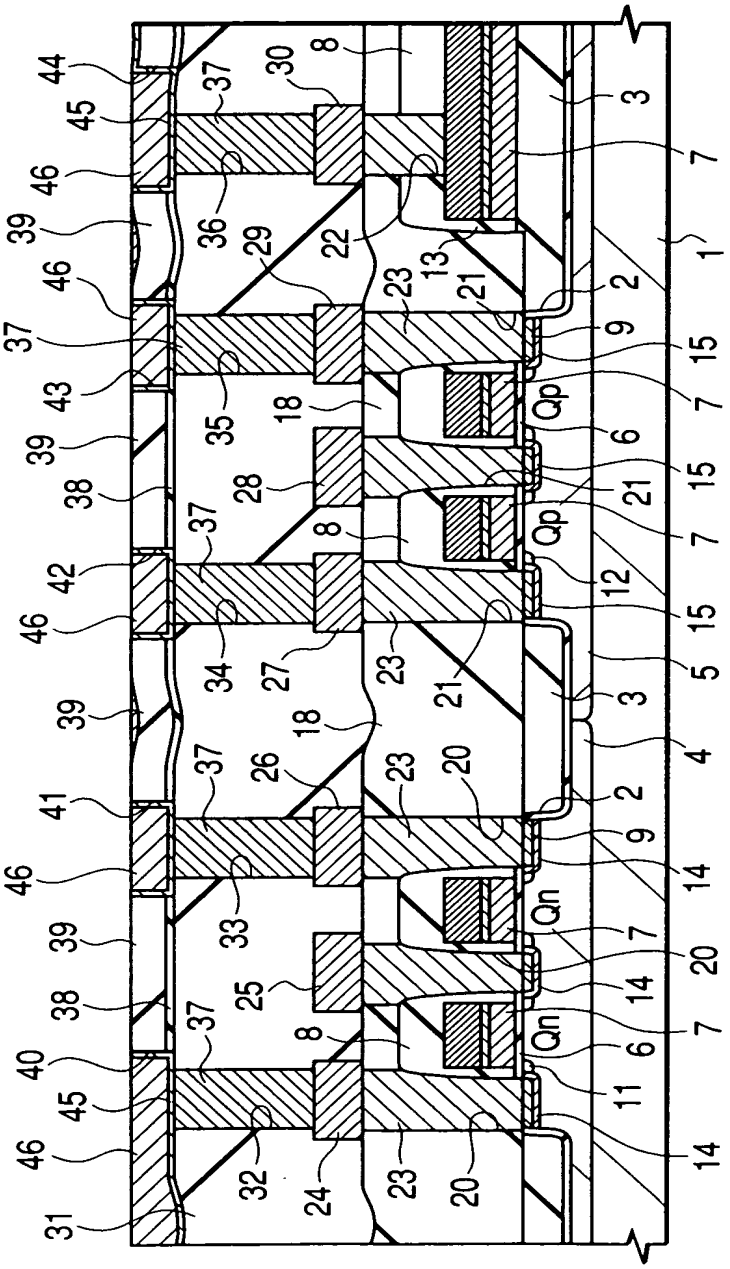


FIG. 40(a)

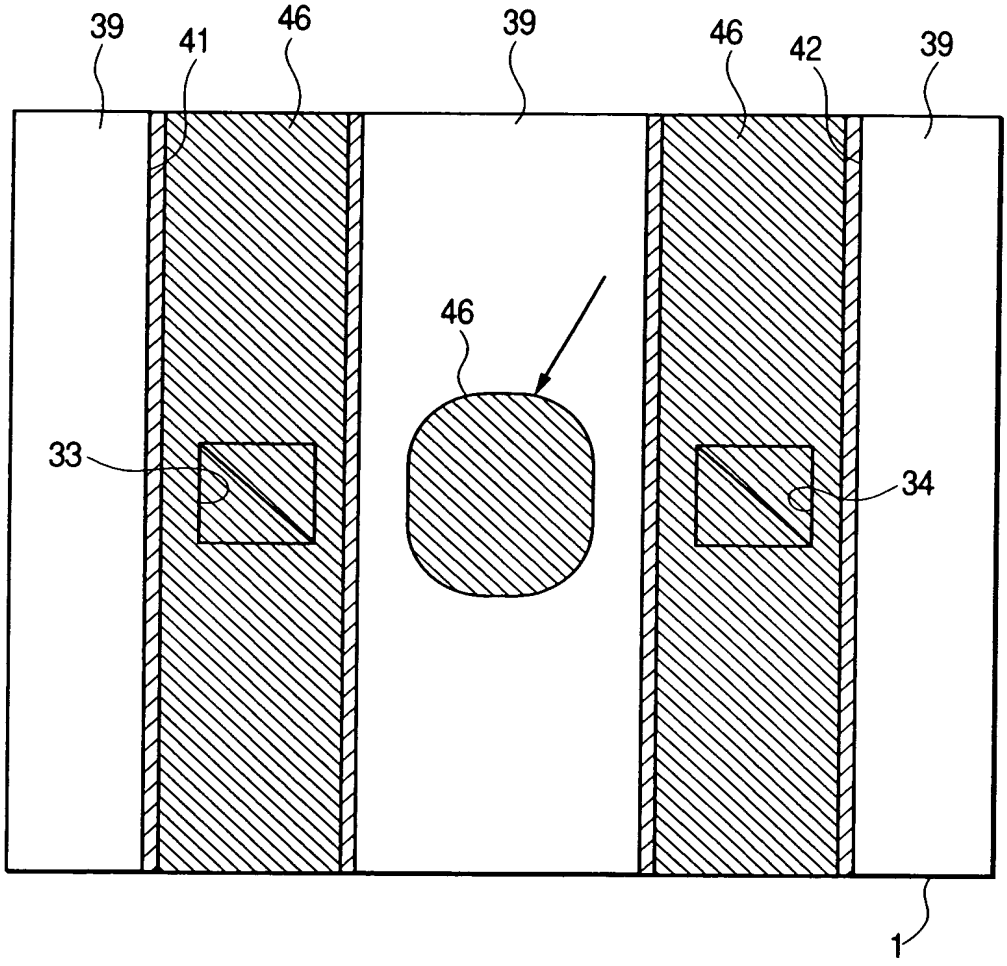


FIG. 40(b)

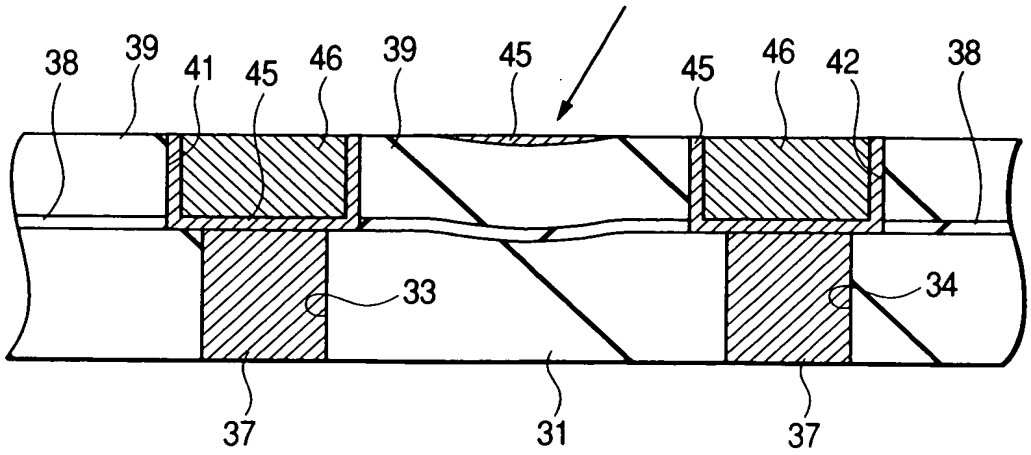
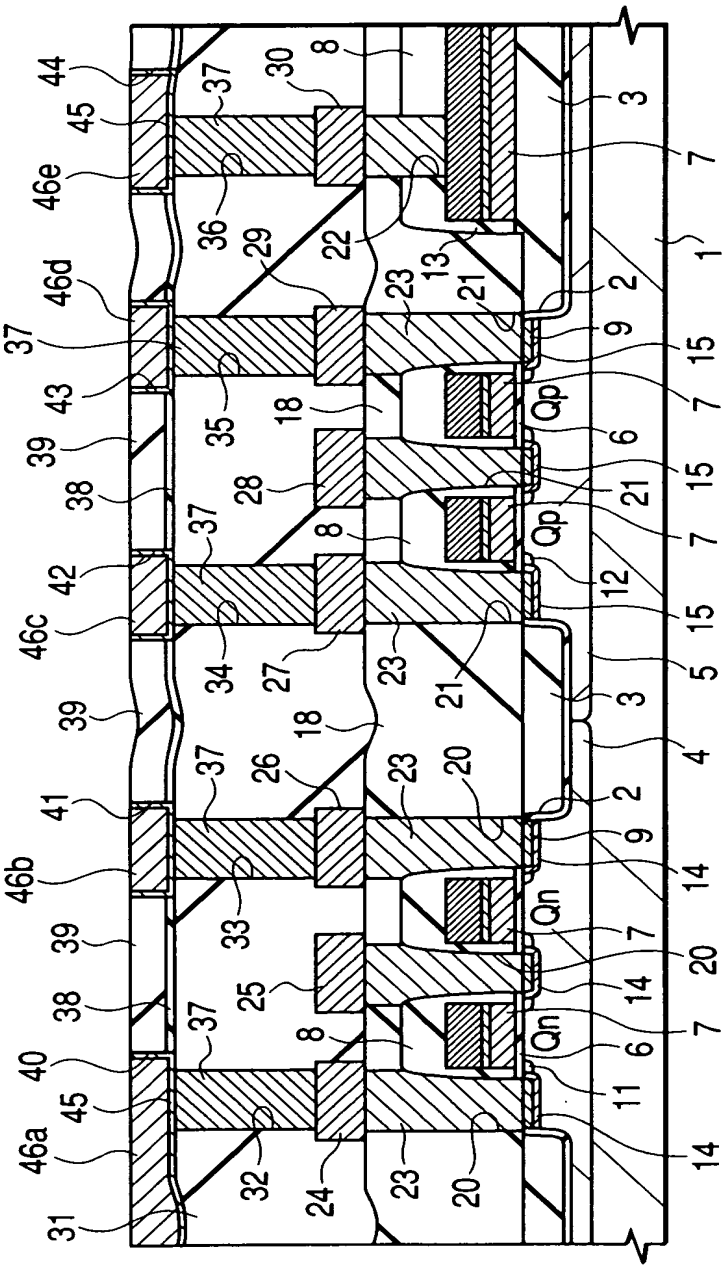


FIG. 41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31
32
33
34
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36
37
38
39
40
41
42
43
44
45
46a
46b
46c
46d
46e
Qp
Qn

FIG. 42(a)

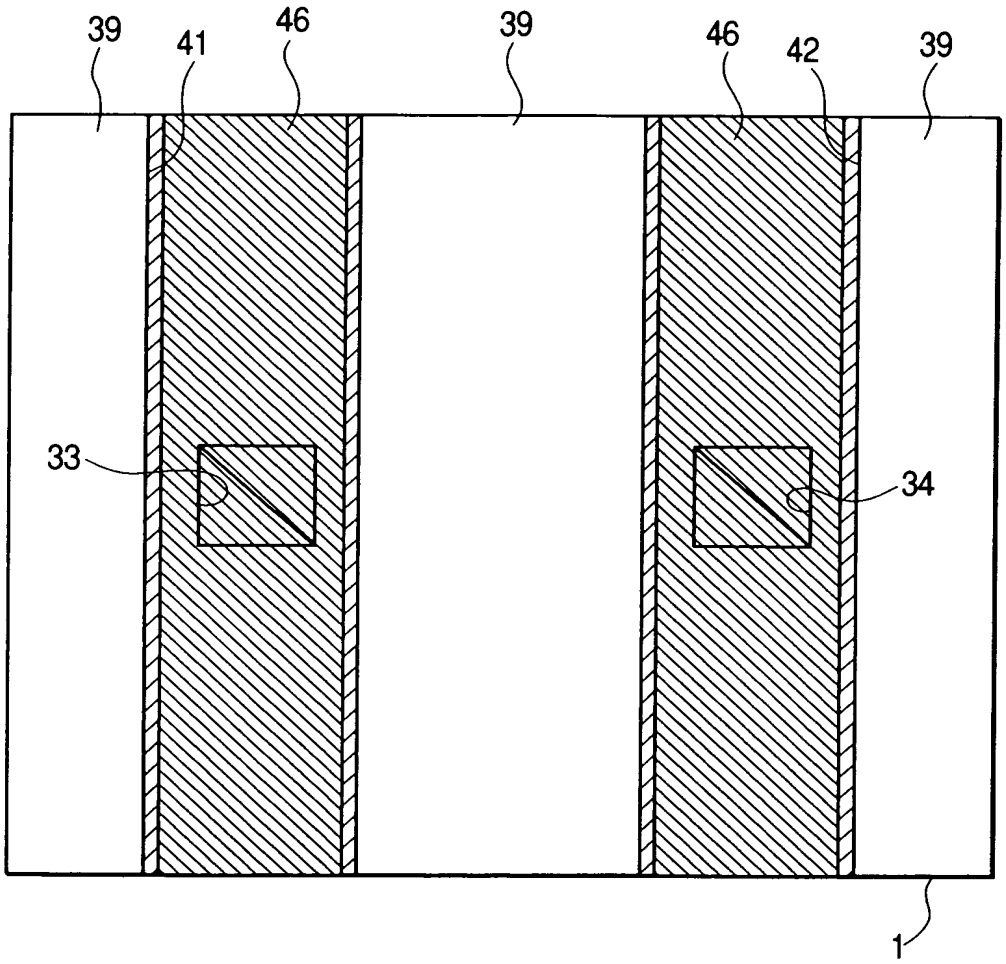


FIG. 42(b)

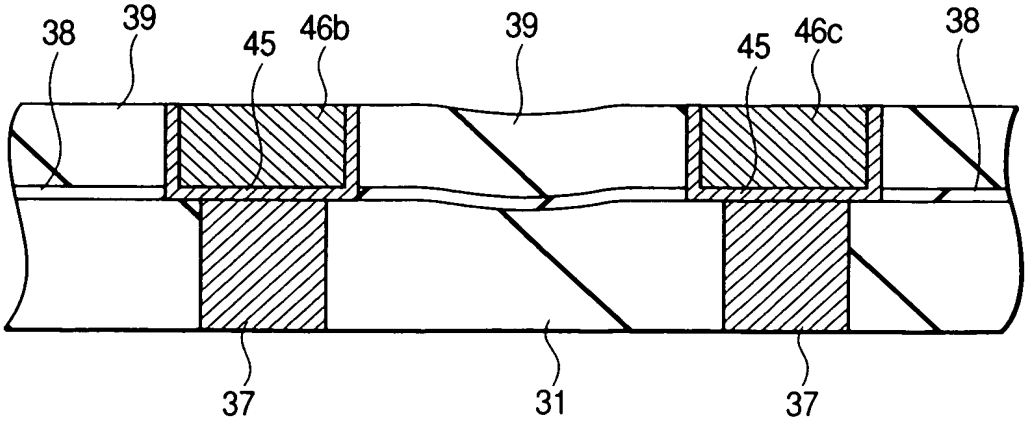


FIG. 43

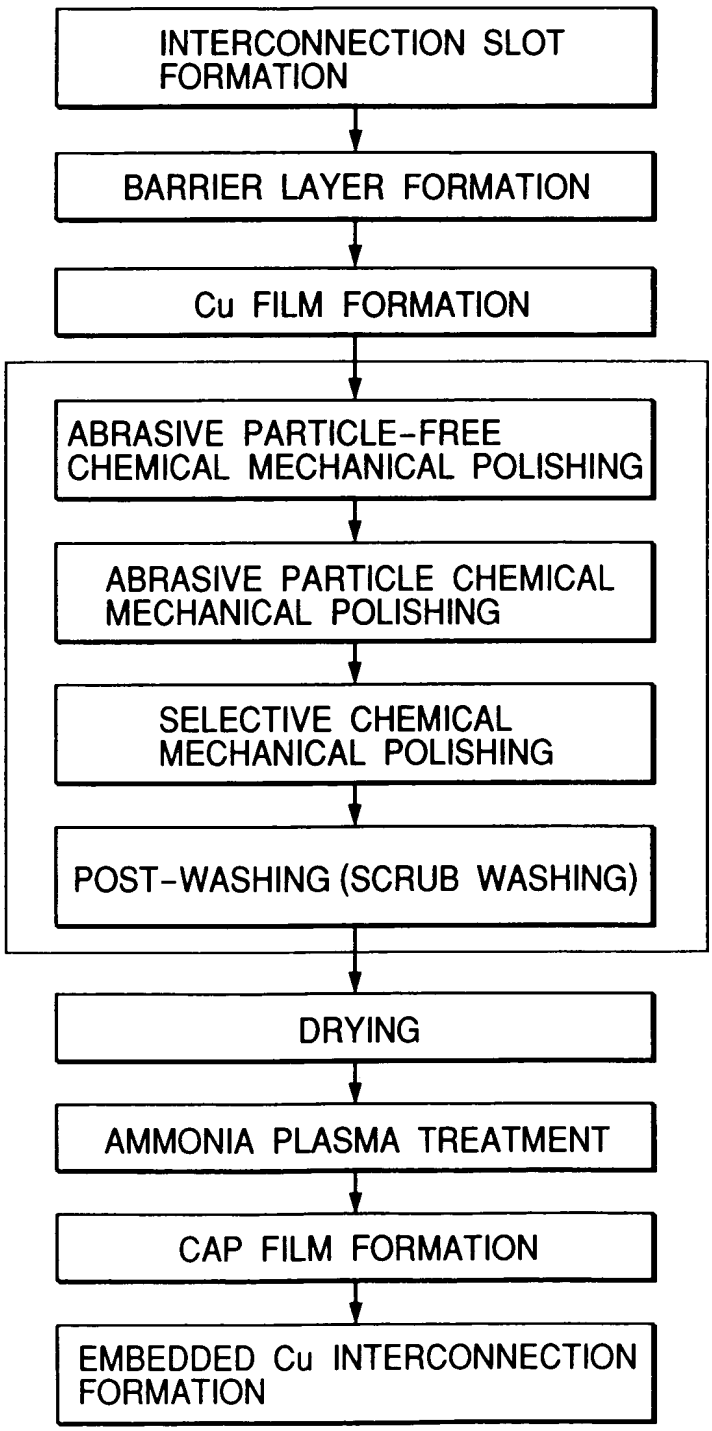

INTERCONNECTION SLOT FORMATION
BARRIER LAYER FORMATION
Cu FILM FORMATION
ABRASIVE PARTICLE-FREE CHEMICAL MECHANICAL POLISHING
ABRASIVE PARTICLE CHEMICAL MECHANICAL POLISHING
SELECTIVE CHEMICAL MECHANICAL POLISHING
POST-WASHING (SCRUB WASHING)
DRYING
AMMONIA PLASMA TREATMENT
CAP FILM FORMATION
EMBEDDED Cu INTERCONNECTION FORMATION

FIG. 44

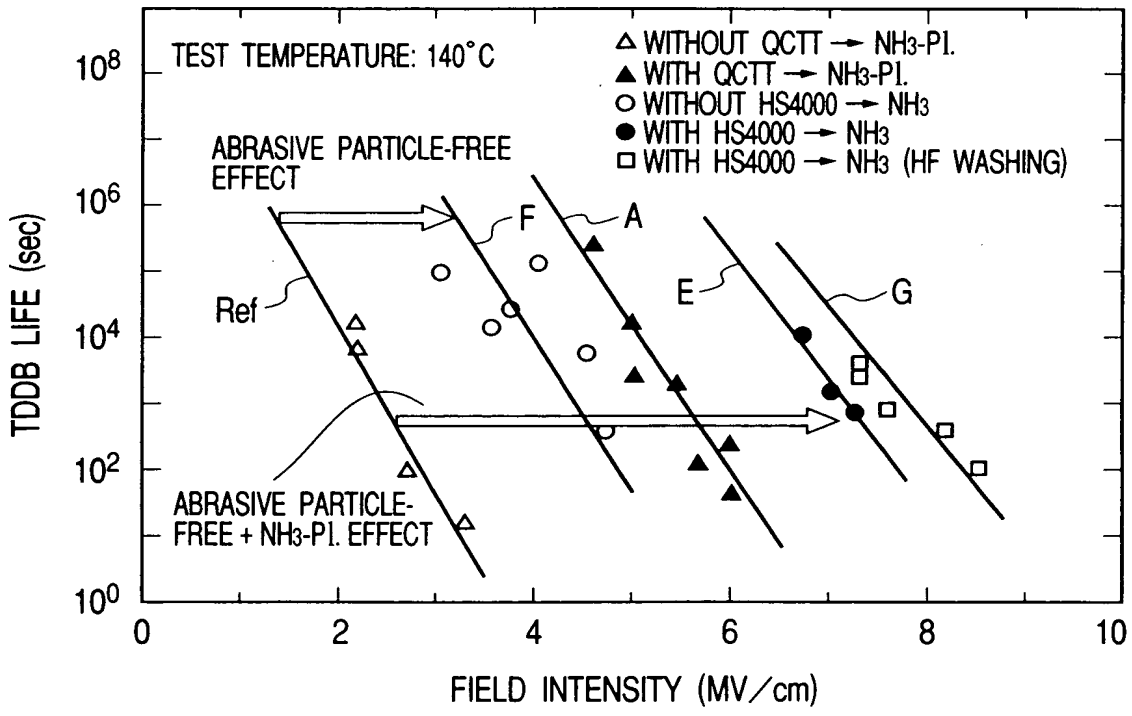

TEST TEMPERATURE: 140°C
△ WITHOUT QCTT → NH3-PI.
▲ WITH QCTT → NH3-PI.
○ WITHOUT HS4000 → NH3
● WITH HS4000 → NH3
□ WITH HS4000 → NH3 (HF WASHING)
ABRASIVE PARTICLE-FREE EFFECT
Ref
F
A
E
G
ABRASIVE PARTICLE-FREE + NH3-PI. EFFECT
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 45

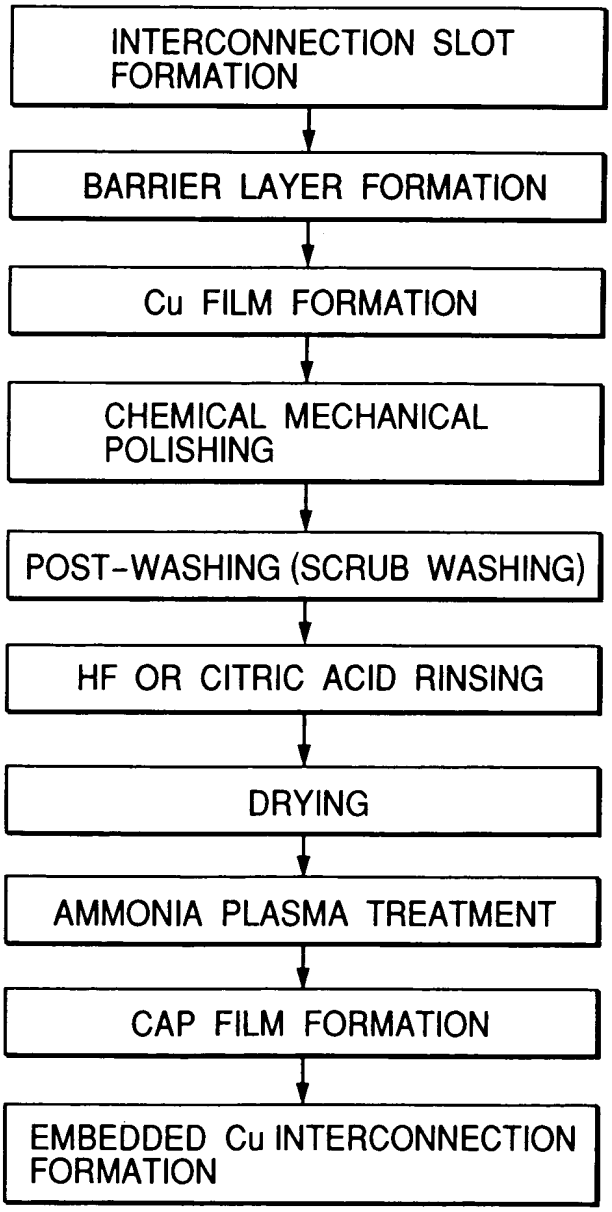


FIG. 46

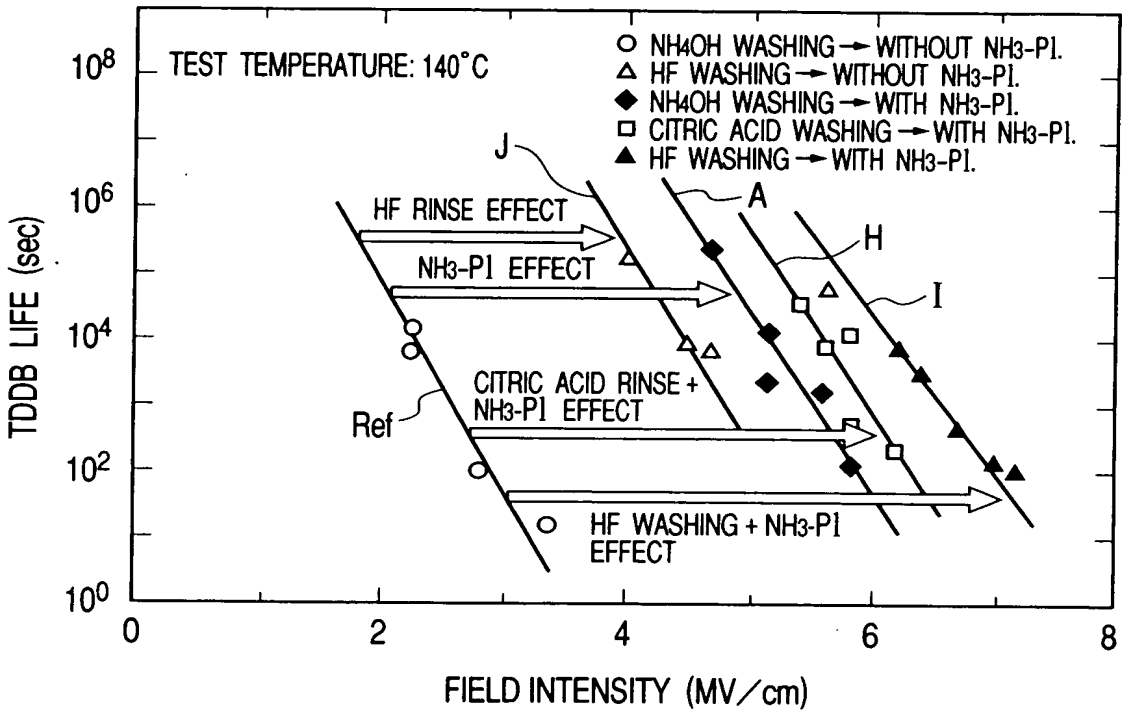

TEST TEMPERATURE: 140°C
NH4OH WASHING → WITHOUT NH3-PI.
HF WASHING → WITHOUT NH3-PI.
NH4OH WASHING → WITH NH3-PI.
CITRIC ACID WASHING → WITH NH3-PI.
HF WASHING → WITH NH3-PI.
J
A
H
I
HF RINSE EFFECT
NH3-PI EFFECT
CITRIC ACID RINSE + NH3-PI EFFECT
Ref
HF WASHING + NH3-PI EFFECT
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8

FIG. 47

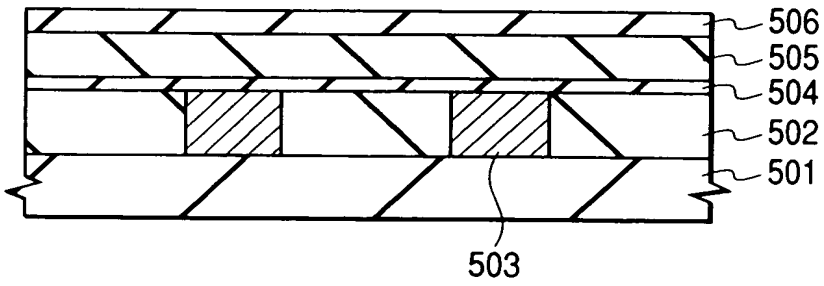

506
505
504
502
501
503

FIG. 48(a)

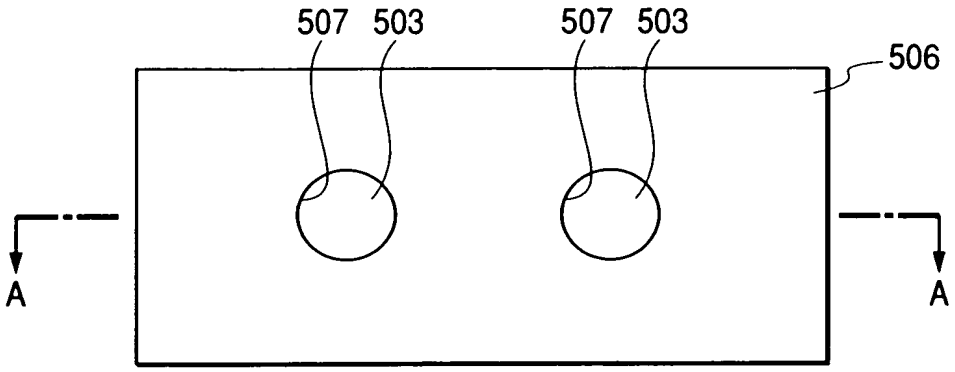


FIG. 48(b)

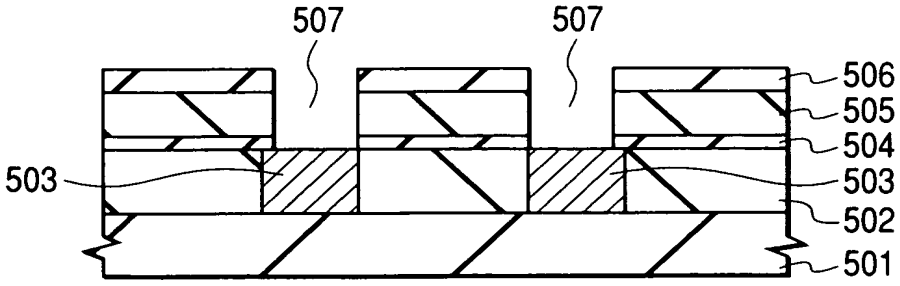
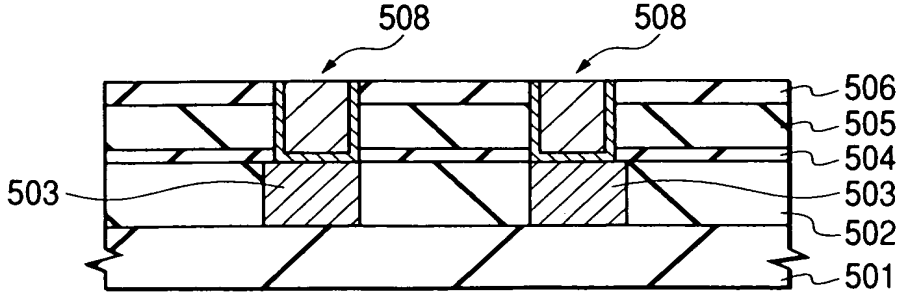


FIG. 49



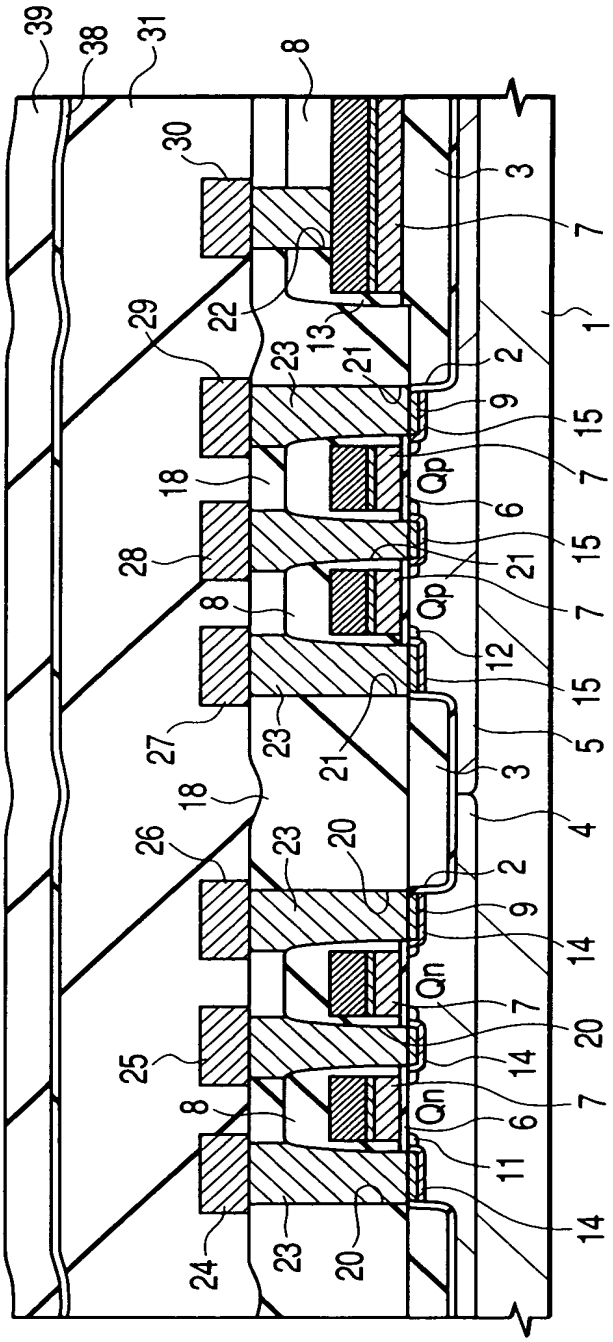

39
38
31
8
30
3
7
1
29
22
23
13
21
2
9
15
18
Qp
6
28
12
27
5
4
26
20
14
25
Qn
11
24

FIG. 50

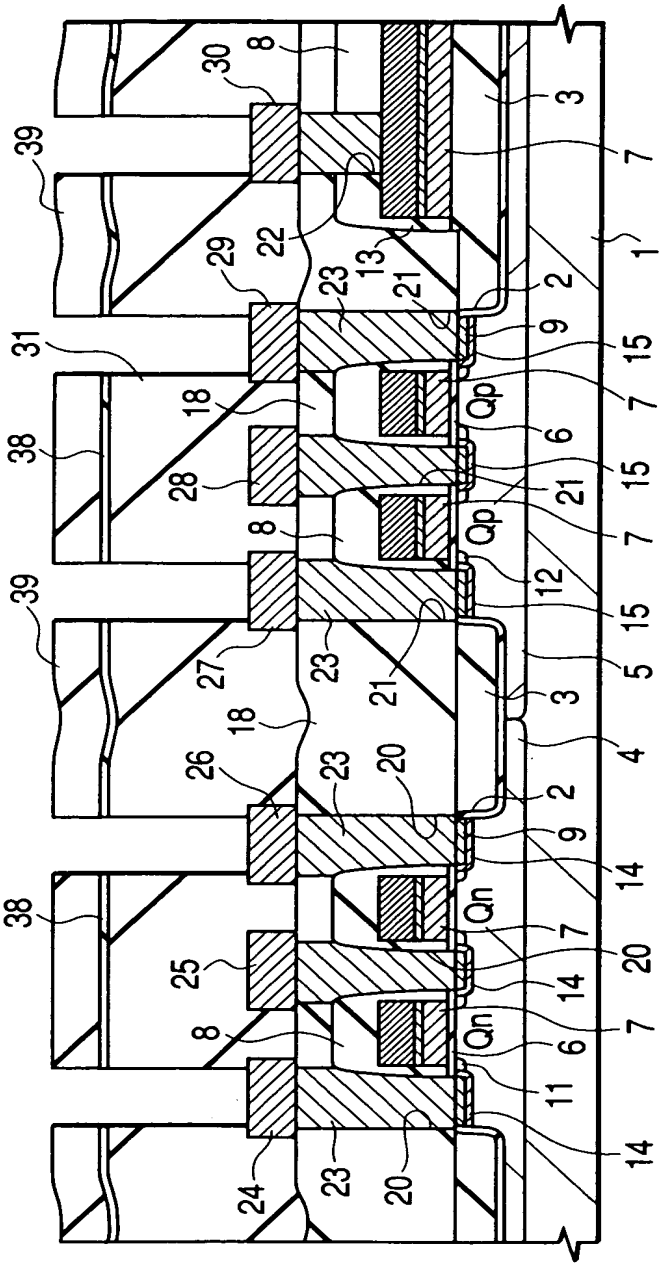

39
30
8
3
7
1
29
22
23
13
21
2
9
15
31
18
Qp
6
38
28
12
27
5
4
26
20
14
25
Qn
11
24

FIG. 51

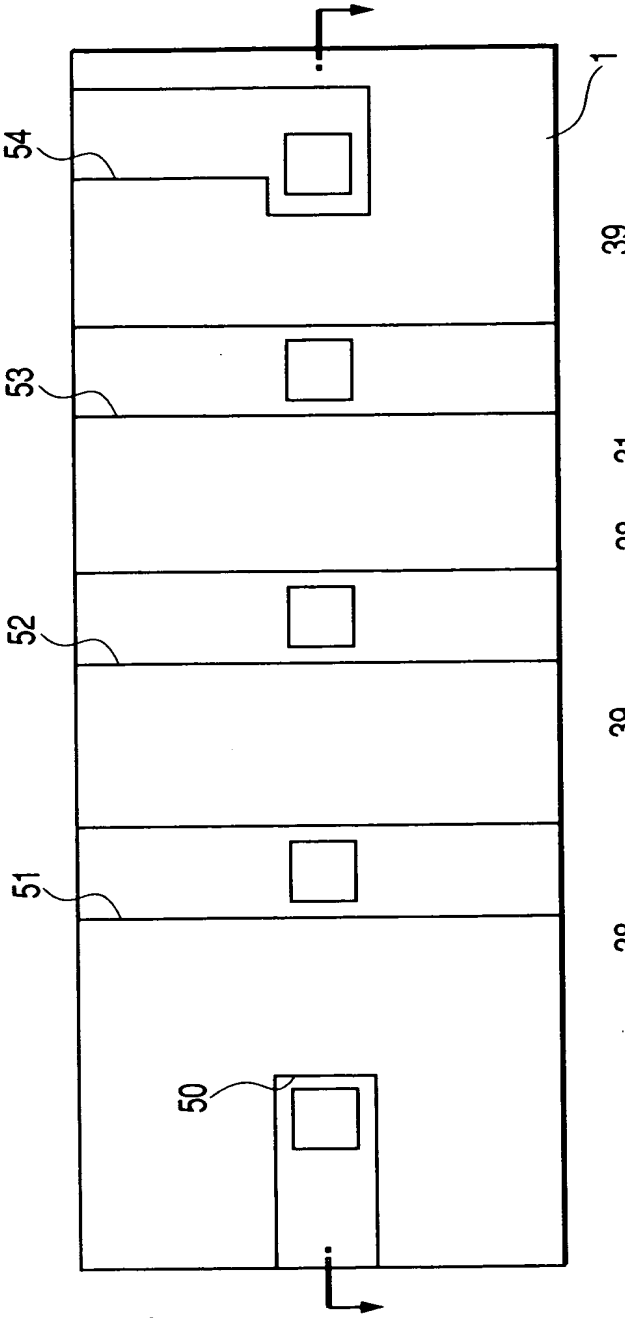


FIG. 52(a)

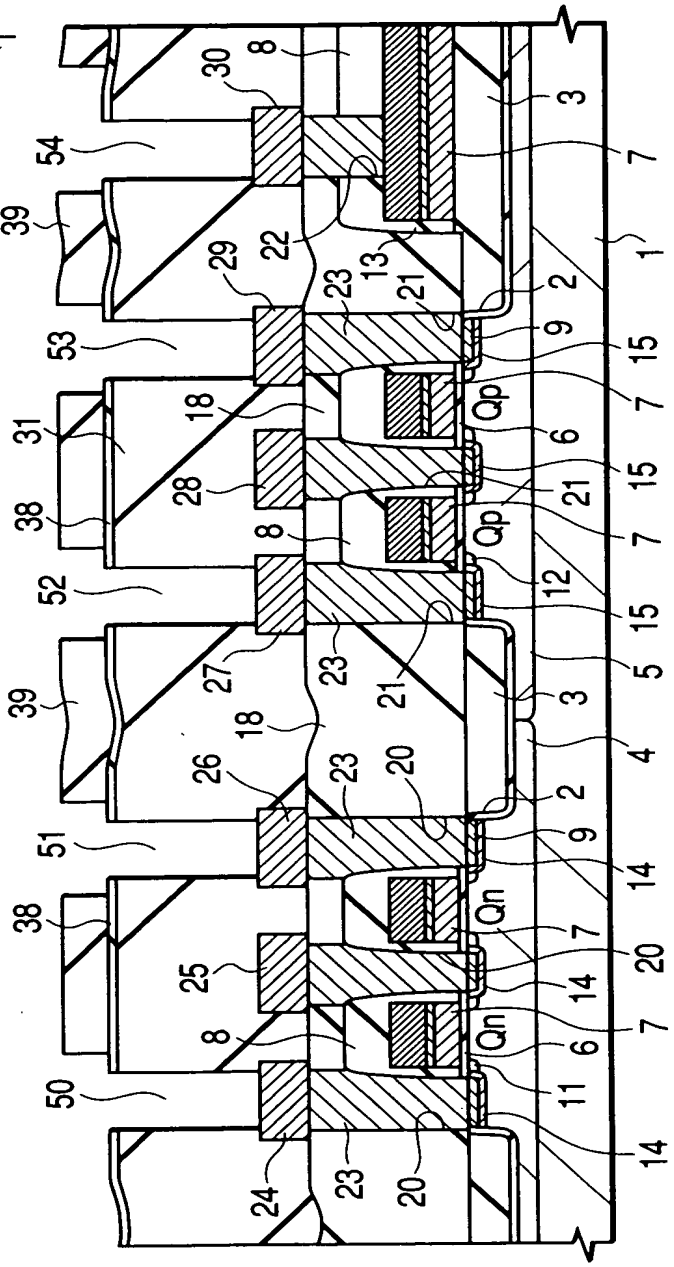
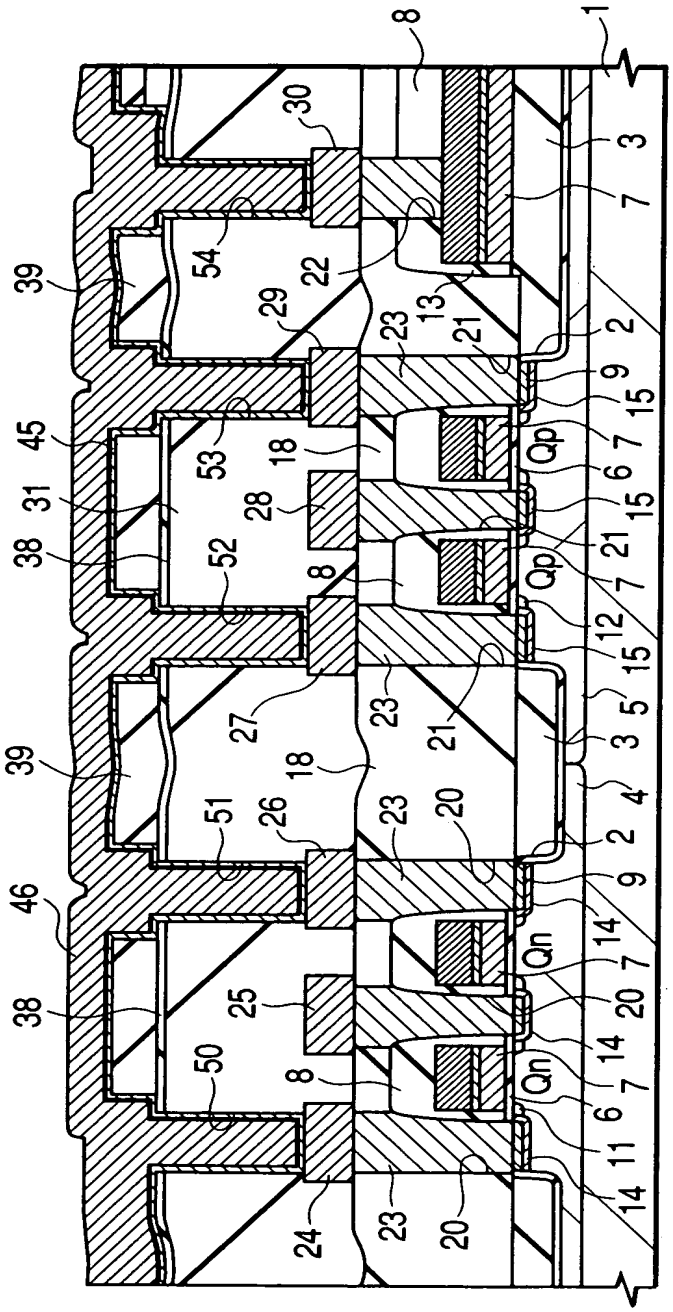


FIG. 52(b)


1
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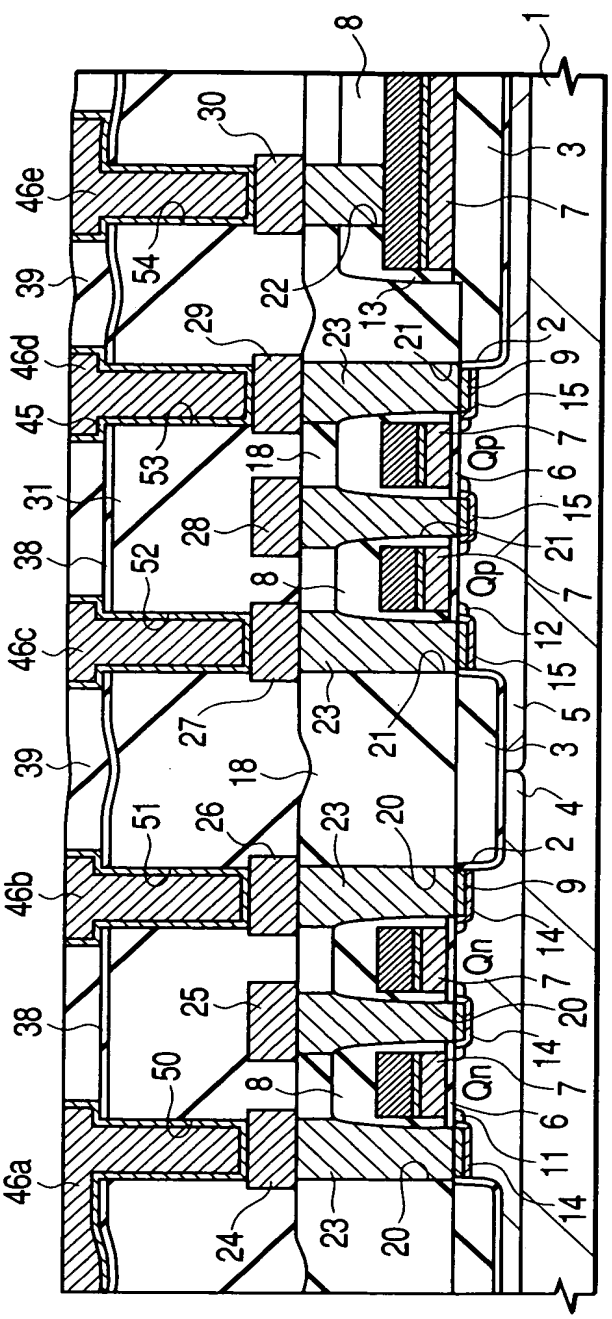
7
8
9
11
12
13
14
15
18
20
21
22
23
24
25
26
27
28
29
30
31
38
39
45
46
50
51
52
53
54
Qp
Qn

FIG. 53


1
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21
22
23
24
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26
27
28
29
30
31
38
39
45
46
46a
46b
46c
46d
46e
50
51
52
53
54
Qp
Qn

FIG. 54

FIG. 55

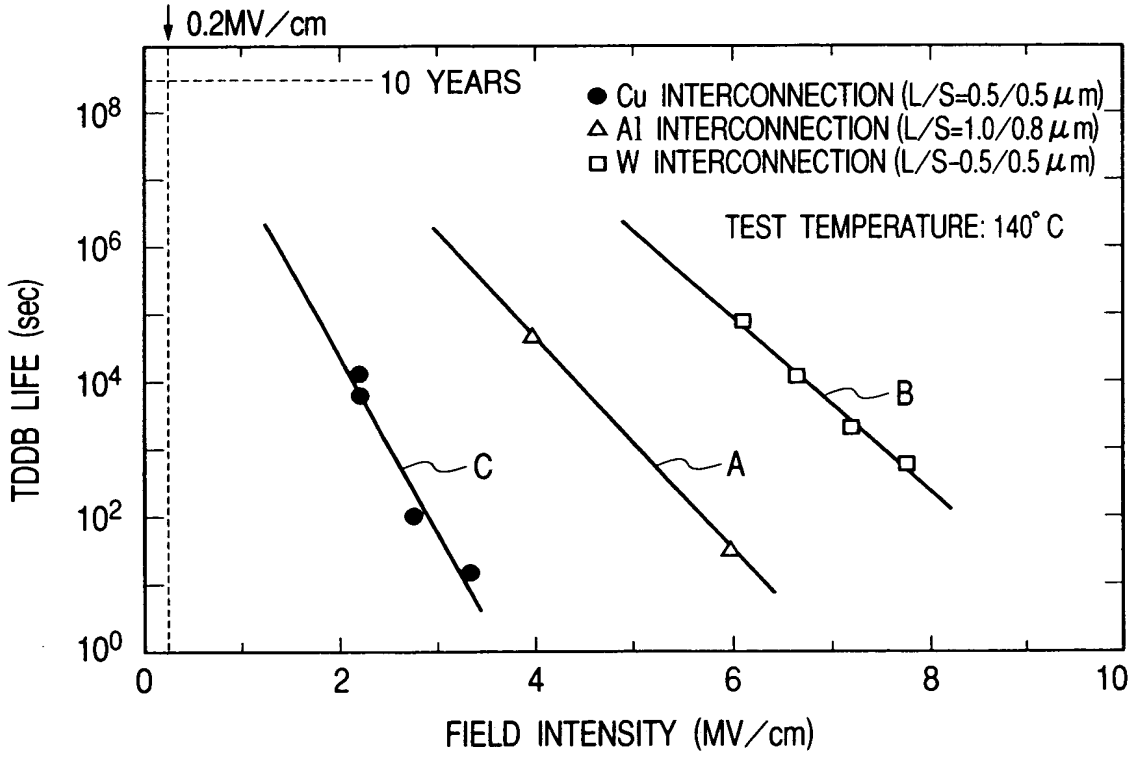

0.2MV/cm
10 YEARS
● Cu INTERCONNECTION (L/S=0.5/0.5 μm)
△ Al INTERCONNECTION (L/S=1.0/0.8 μm)
□ W INTERCONNECTION (L/S-0.5/0.5 μm)
TEST TEMPERATURE: 140° C
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
A
B
C
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 56

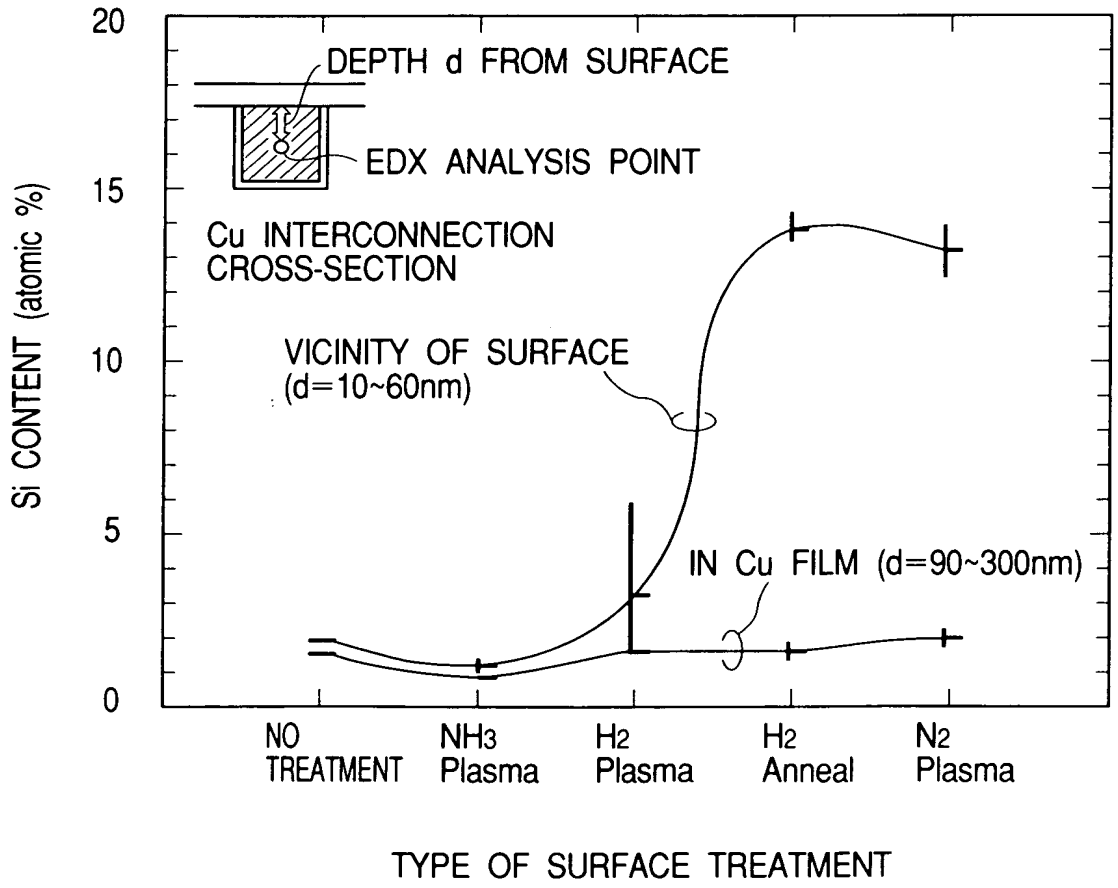
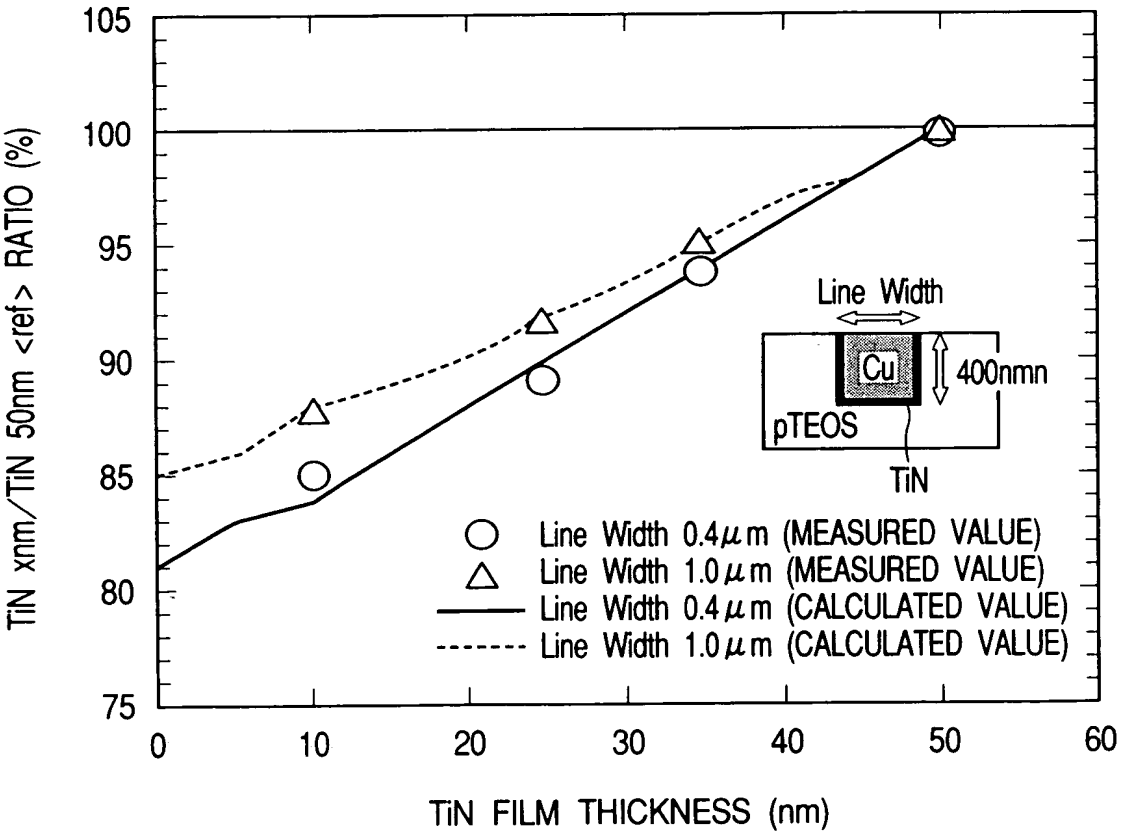

20
15
10
5
0
Si CONTENT (atomic %)
DEPTH d FROM SURFACE
EDX ANALYSIS POINT
Cu INTERCONNECTION
CROSS-SECTION
VICINITY OF SURFACE
(d=10~60nm)
IN Cu FILM (d=90~300nm)
NO TREATMENT
NH3 Plasma
H2 Plasma
H2 Anneal
N2 Plasma
TYPE OF SURFACE TREATMENT

FIG. 57



*TiN FILM THICKNESS=FILM THICKNESS AT BASE OF SLOT

FIG. 58

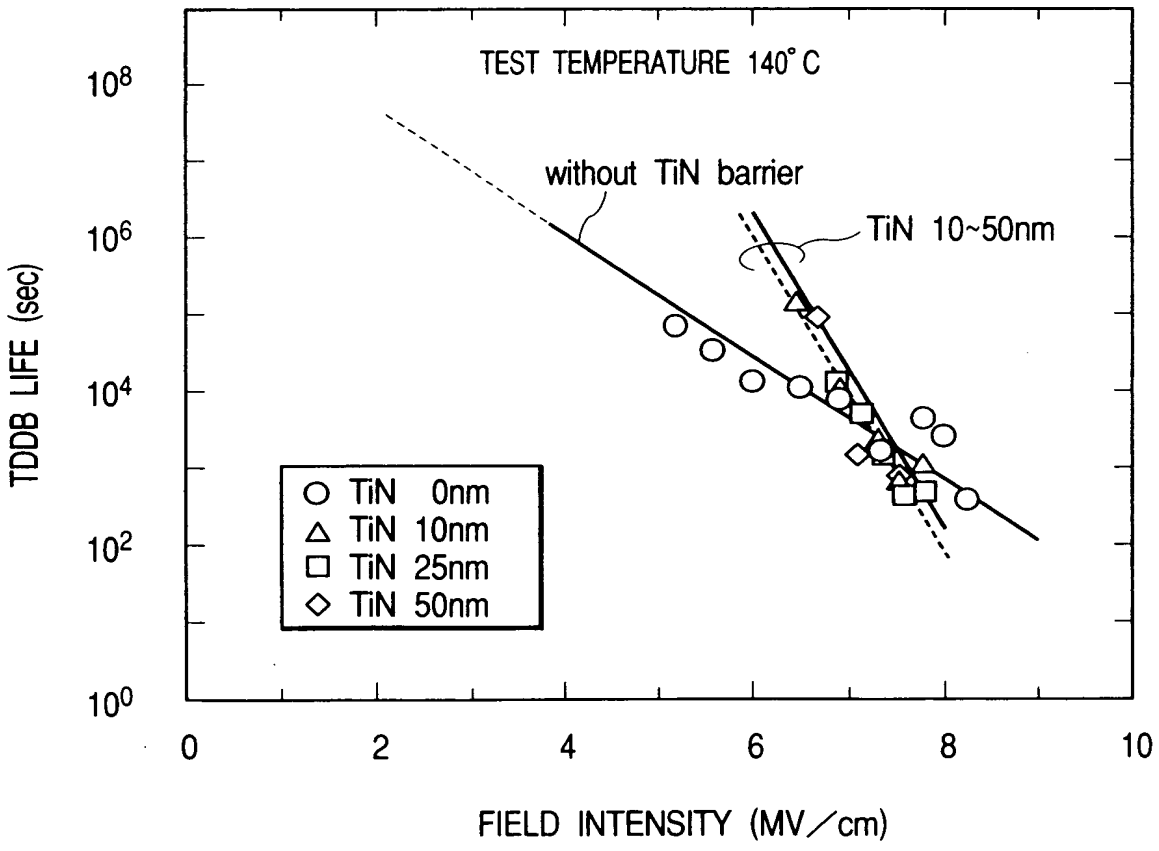

TEST TEMPERATURE 140° C
without TiN barrier
TiN 10~50nm
TiN 0nm
TiN 10nm
TiN 25nm
TiN 50nm
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 59

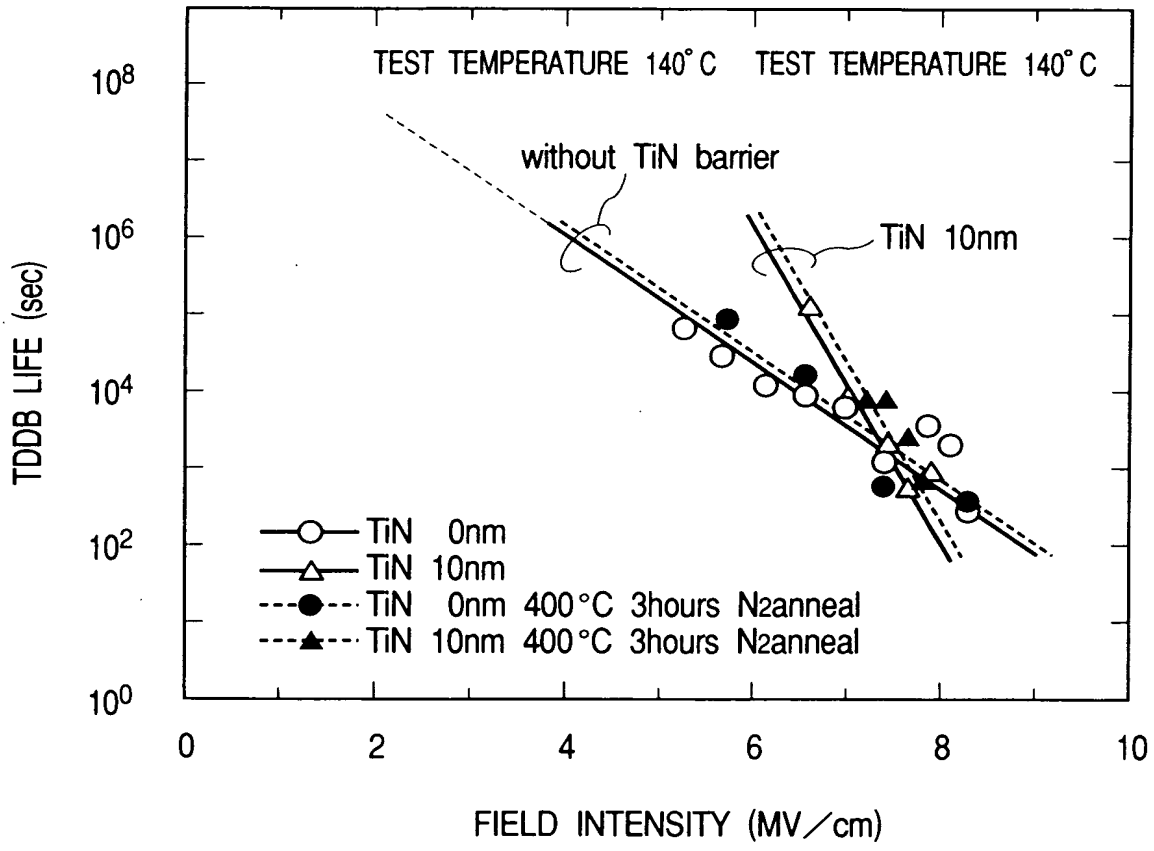

TEST TEMPERATURE 140°C
TEST TEMPERATURE 140°C
without TiN barrier
TiN 10nm
TiN 0nm
TiN 10nm
TiN 0nm 400°C 3hours N2anneal
TiN 10nm 400°C 3hours N2anneal
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 60(a)

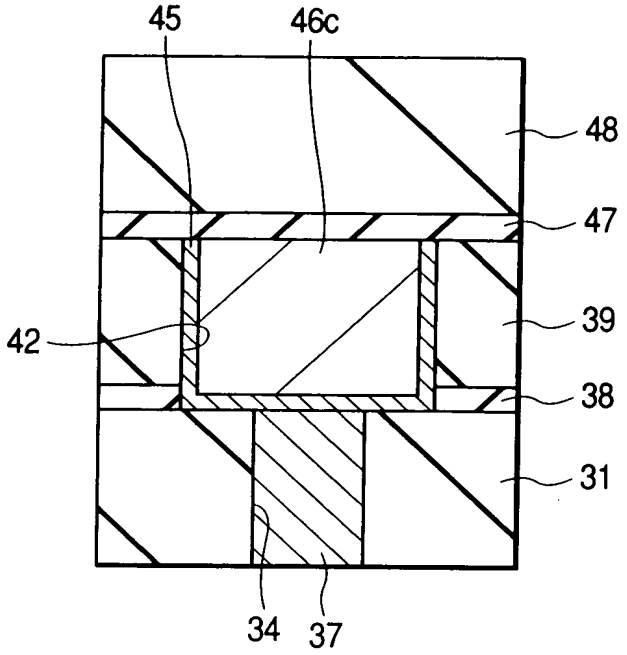


FIG. 60(b)

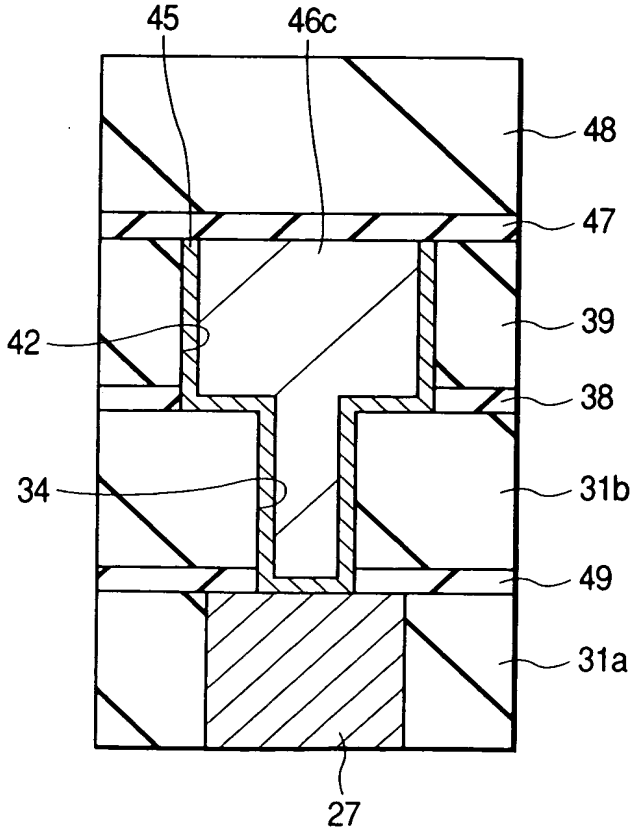


FIG. 61(a)

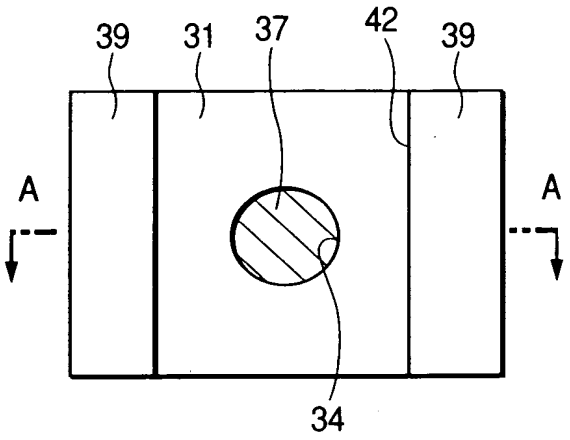


FIG. 61(b)

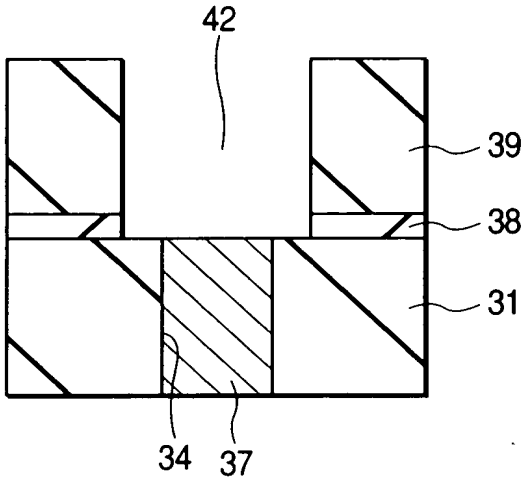


FIG. 62(a)

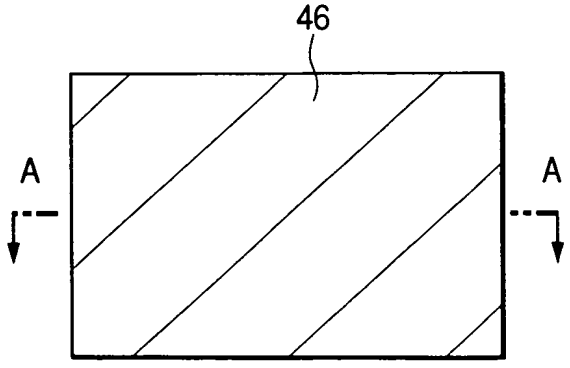


FIG. 62(b)

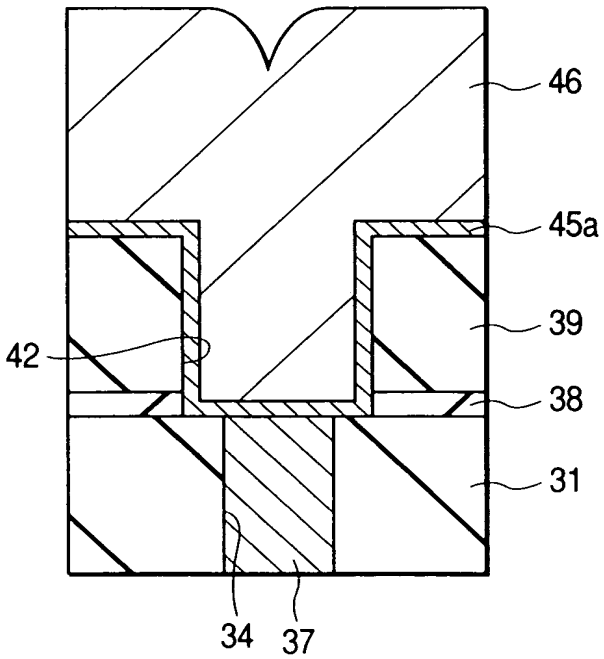


FIG. 63(a)

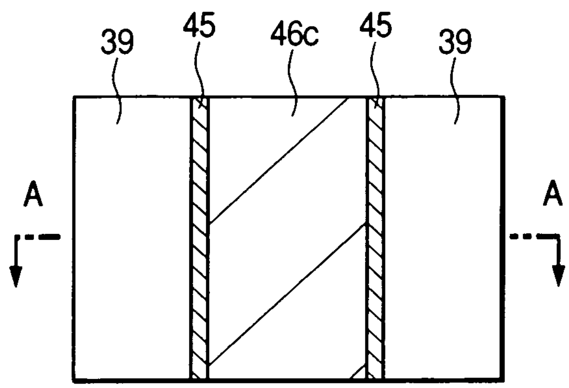


FIG. 63(b)

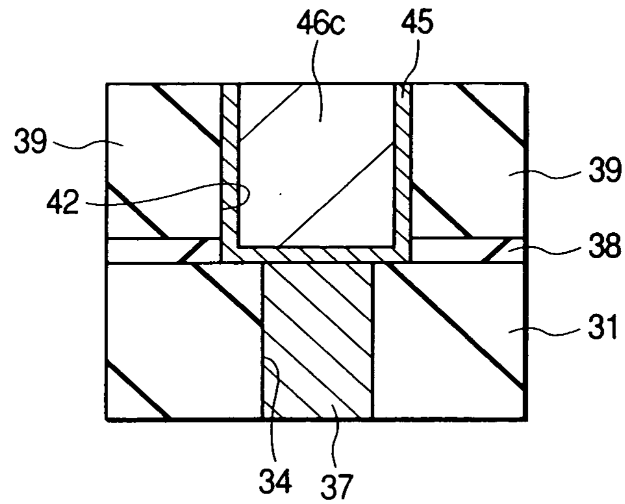


FIG. 64(a)

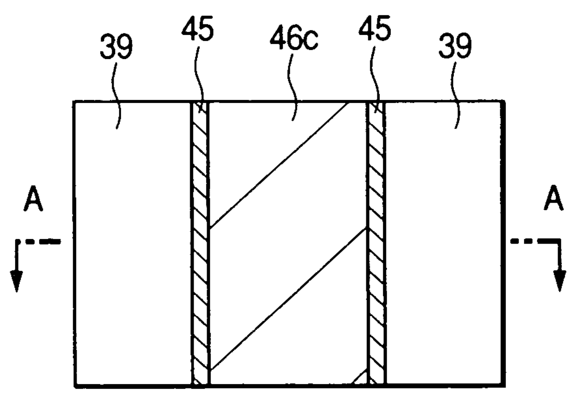


FIG. 64(b)

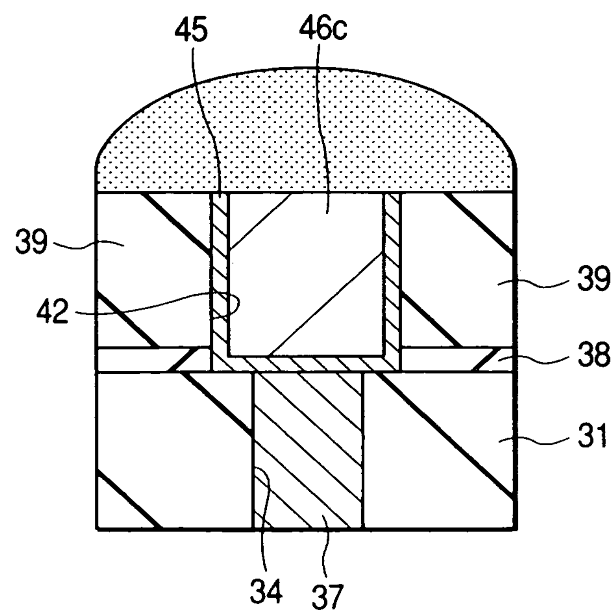


FIG. 65(a)

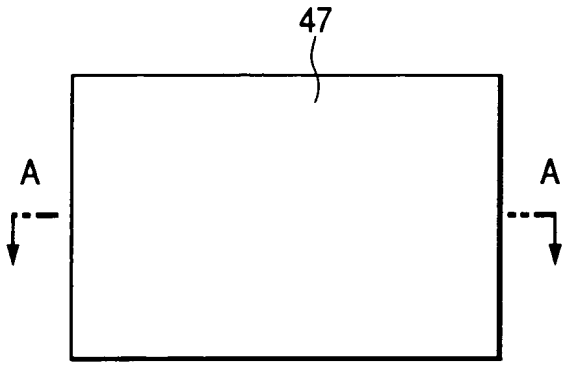


FIG. 65(b)

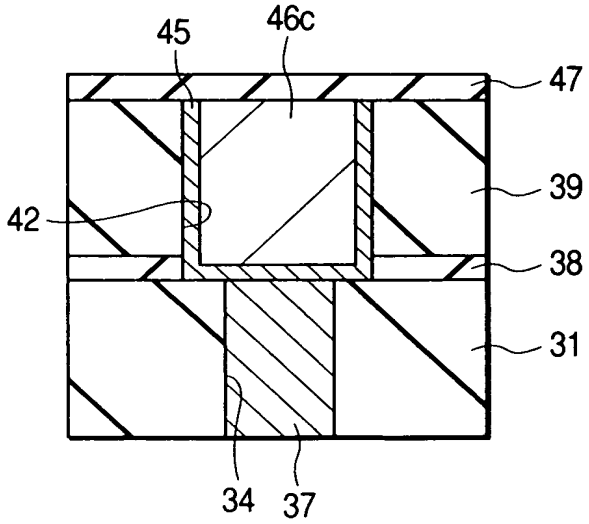


FIG. 66(a)

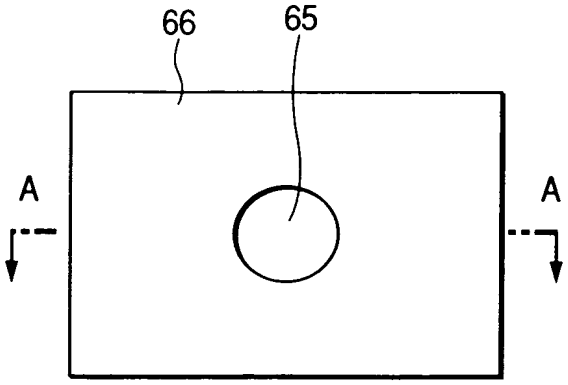


FIG. 66(b)

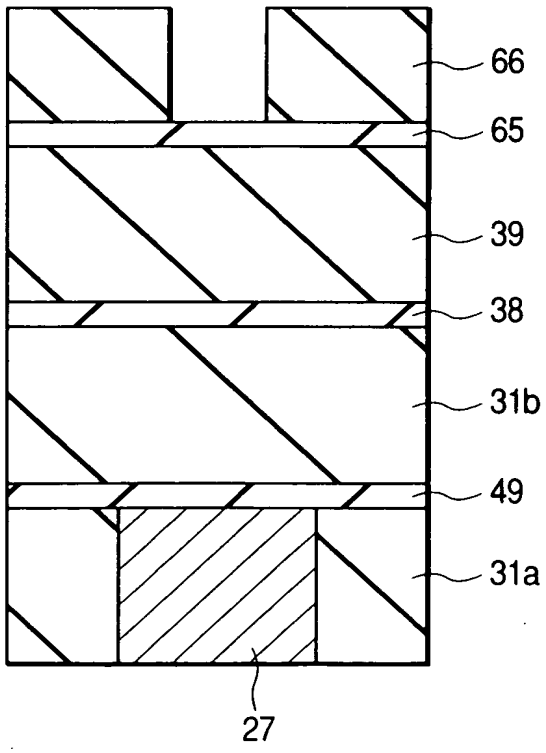


FIG. 67(a)

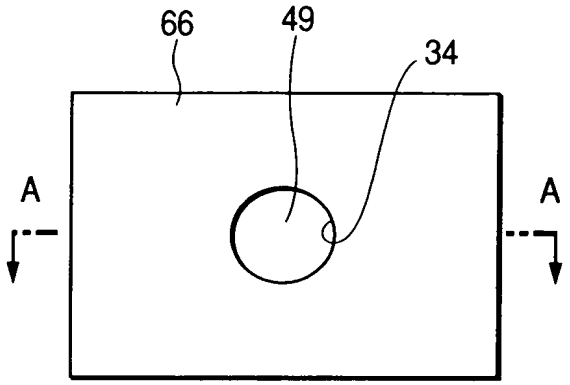


FIG. 67(b)

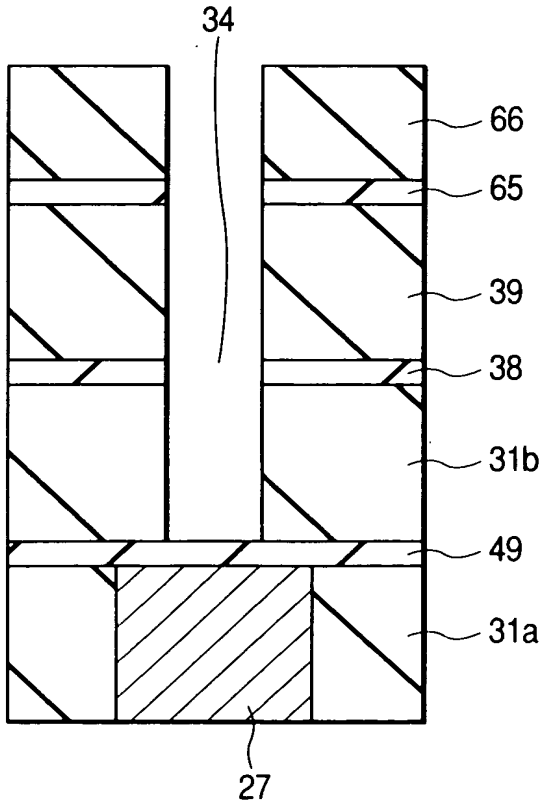


FIG. 68(a)

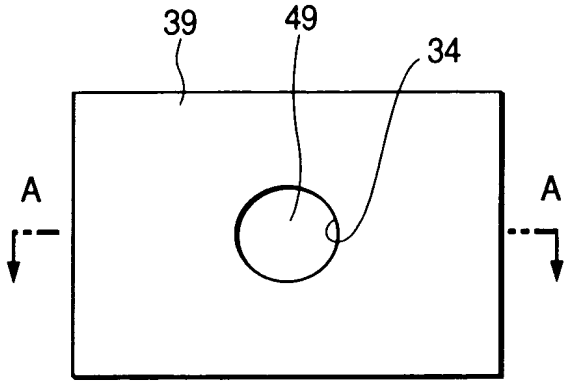


FIG. 68(b)

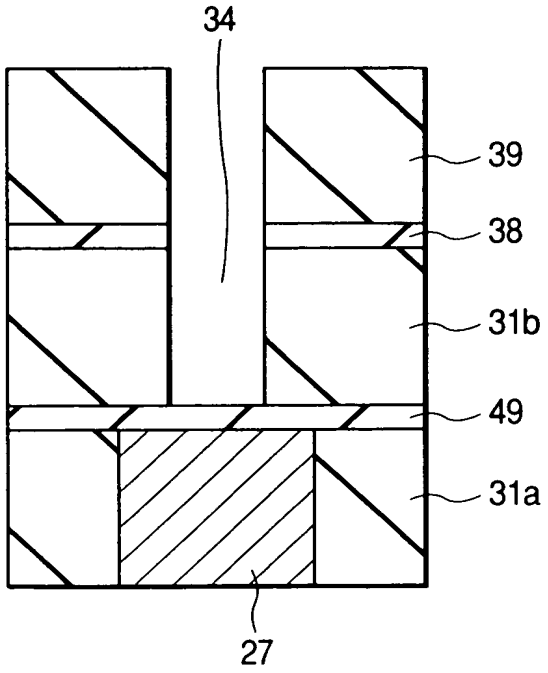


FIG. 69(a)

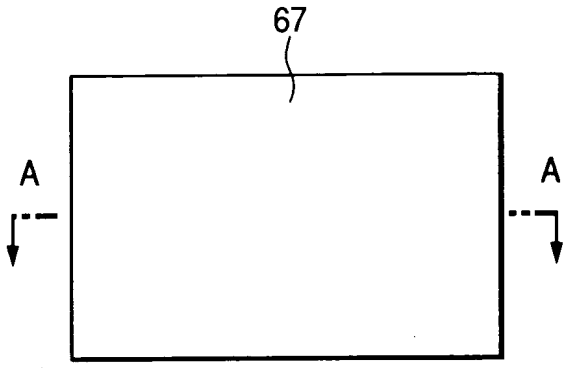


FIG. 69(b)

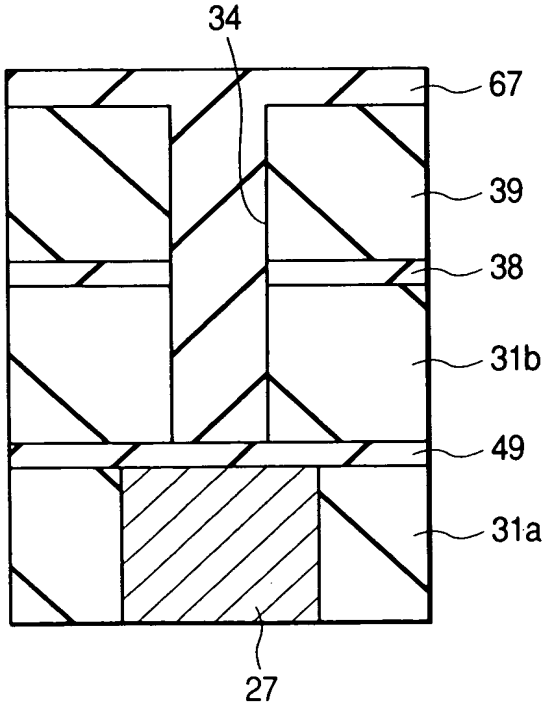


FIG. 70(a)

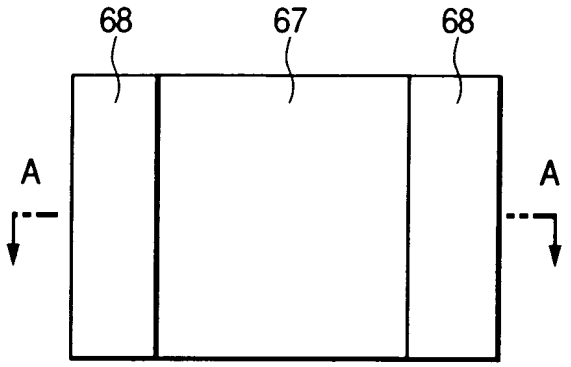


FIG. 70(b)

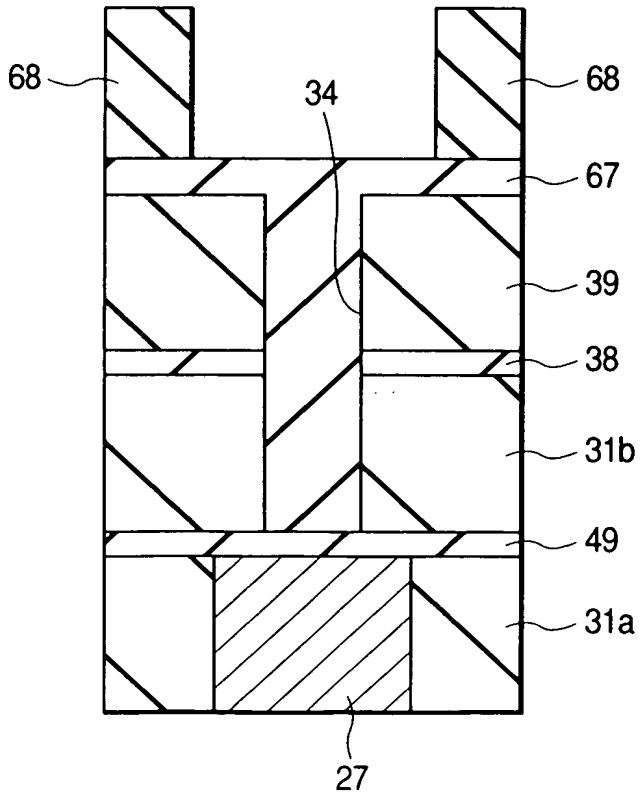


FIG. 71(a)

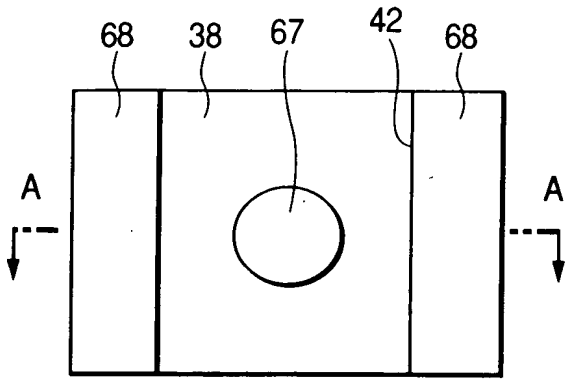


FIG. 71(b)

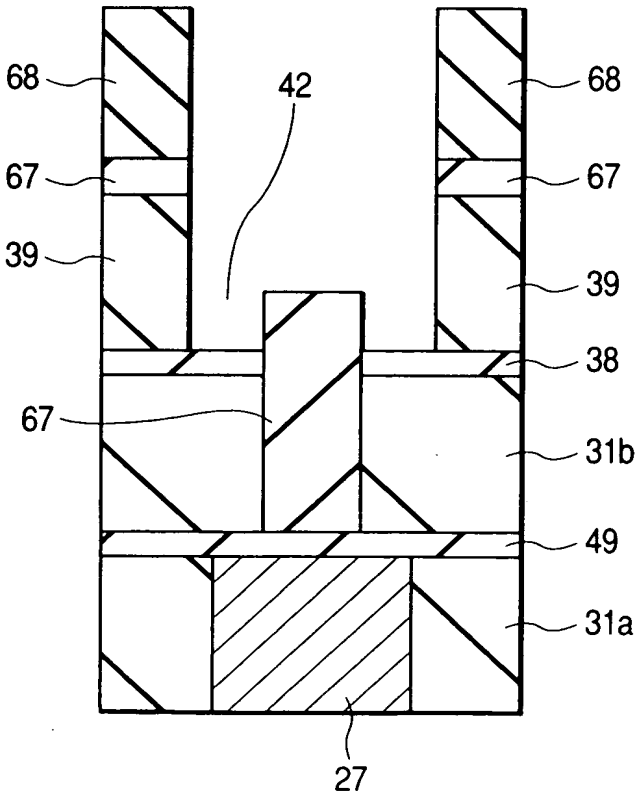


FIG. 72(a)

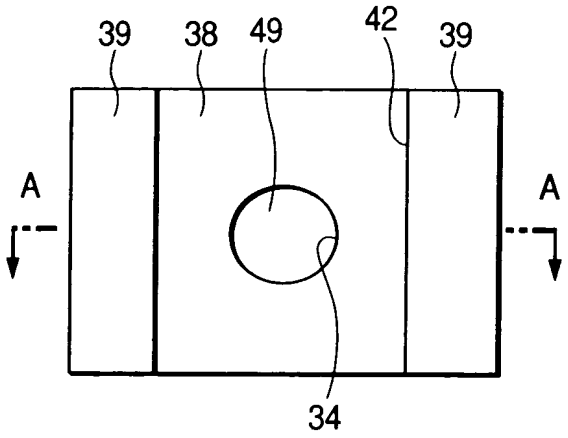


FIG. 72(b)

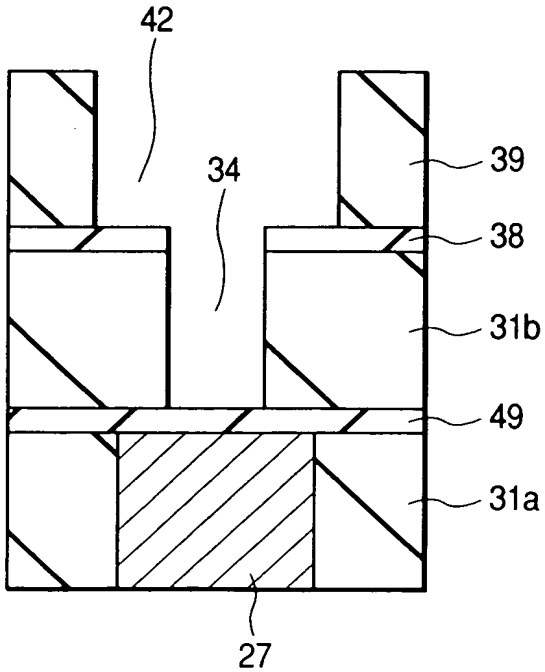


FIG. 73(a)

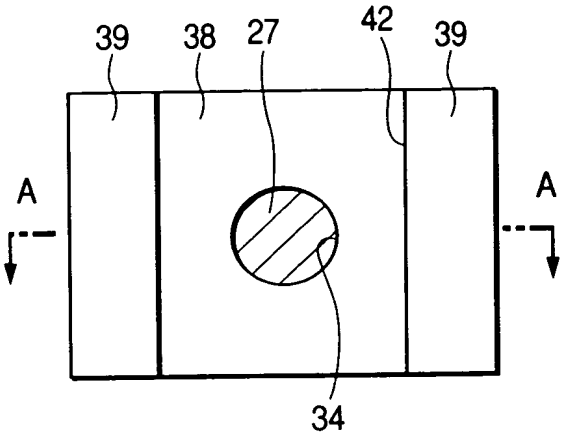


FIG. 73(b)

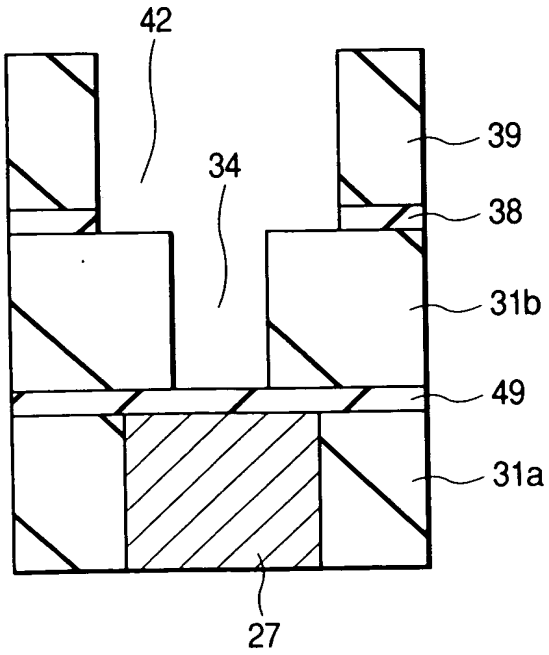


FIG. 74(a)

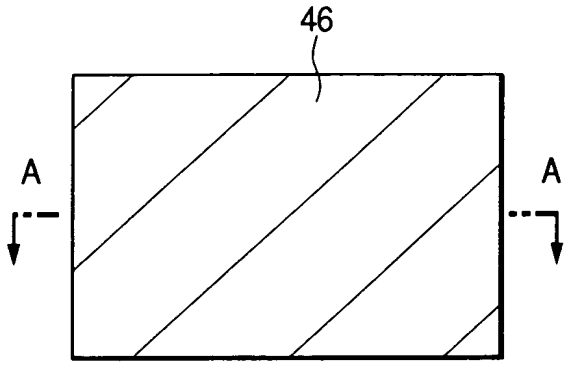


FIG. 74(b)

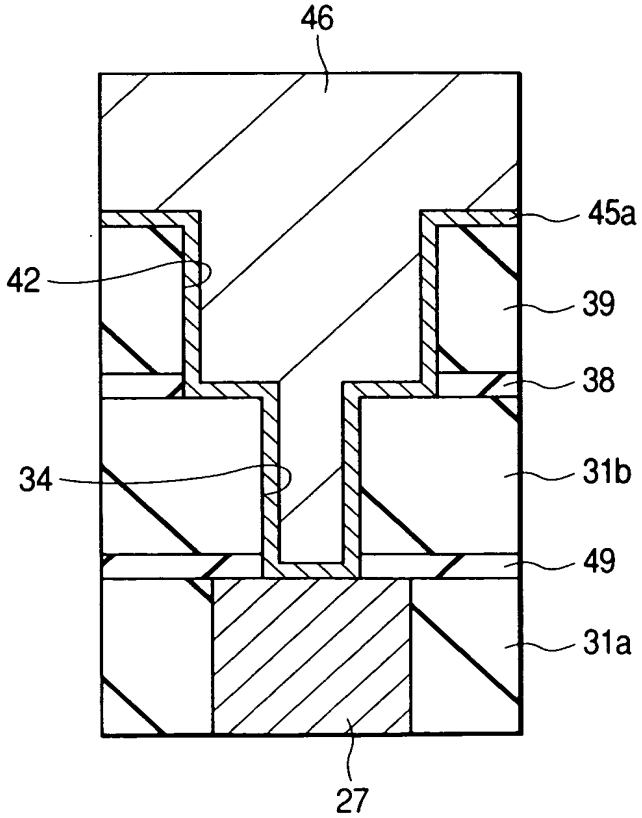


FIG. 75(a)

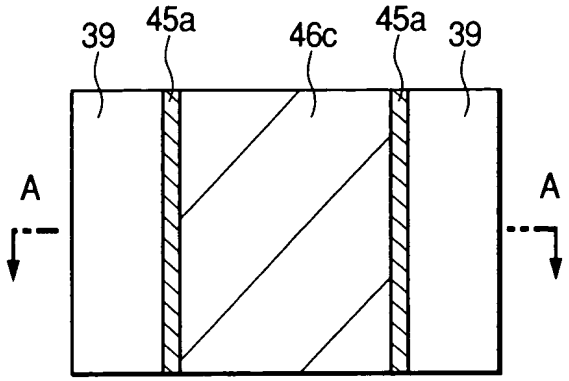


FIG. 75(b)

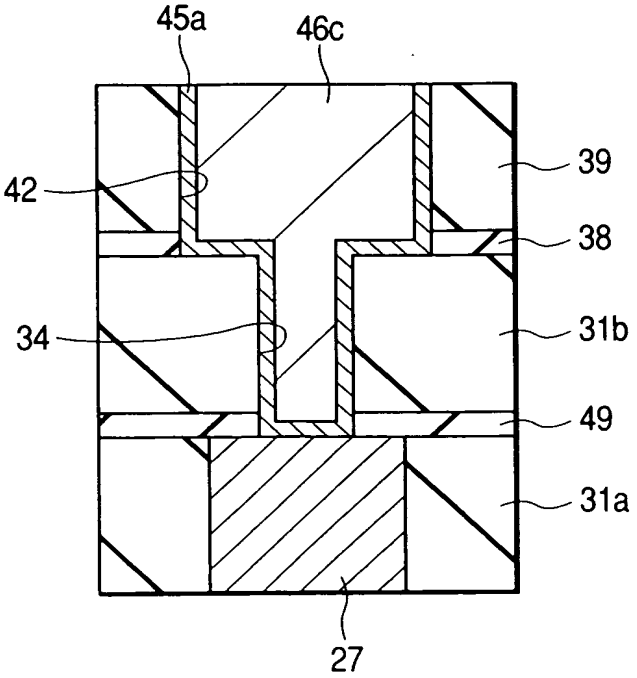


FIG. 76(a)

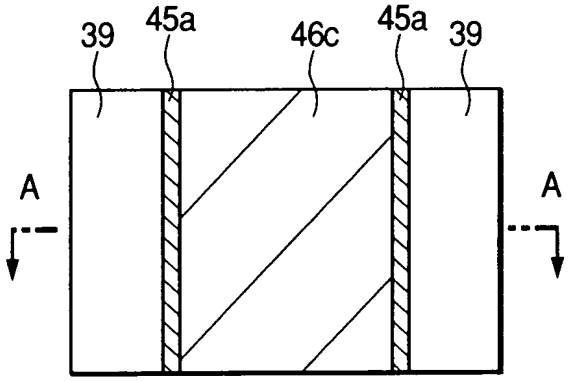


FIG. 76(b)

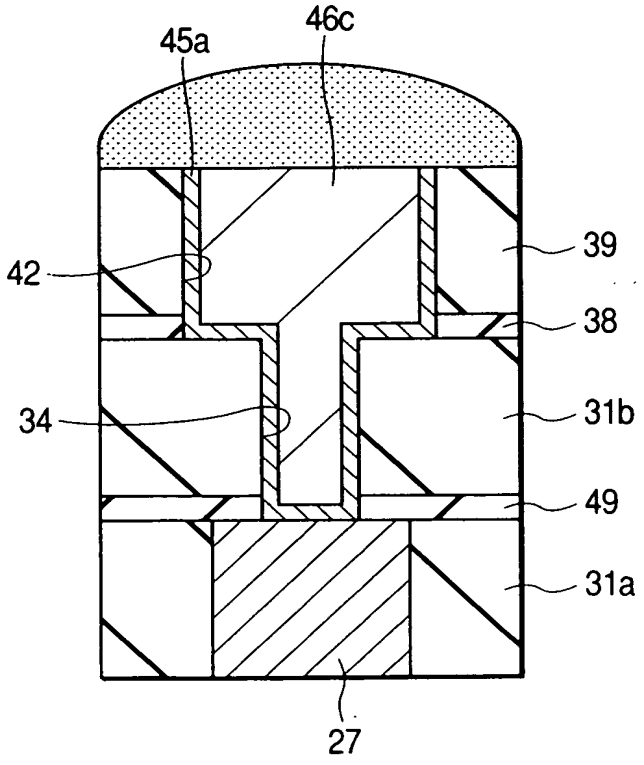


FIG. 77(a)

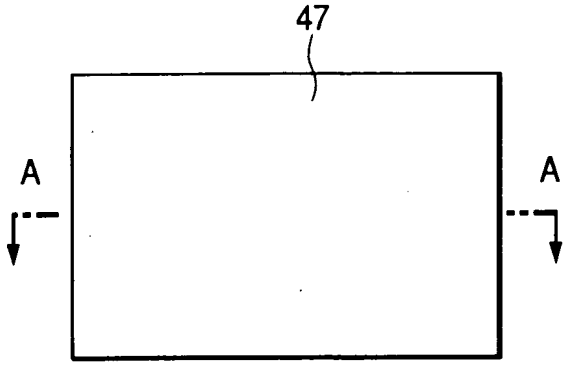


FIG. 77(b)

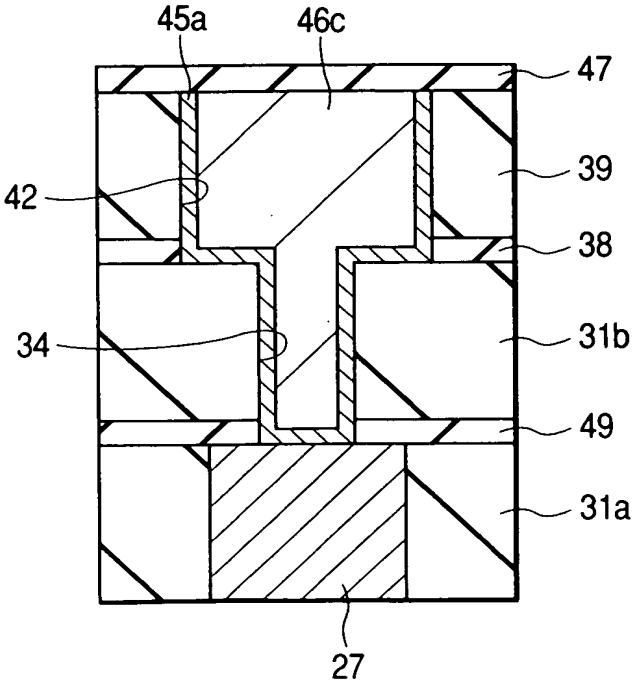


FIG. 78(a)

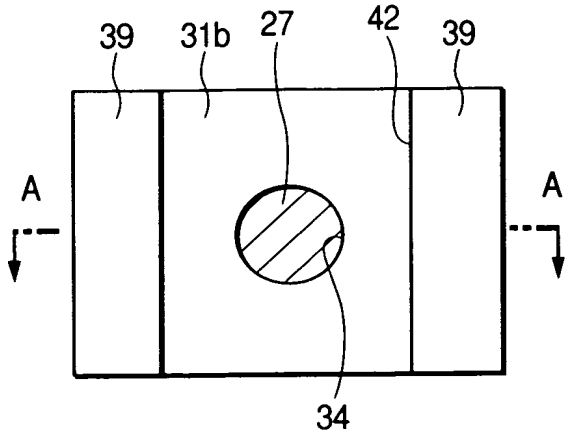


FIG. 78(b)

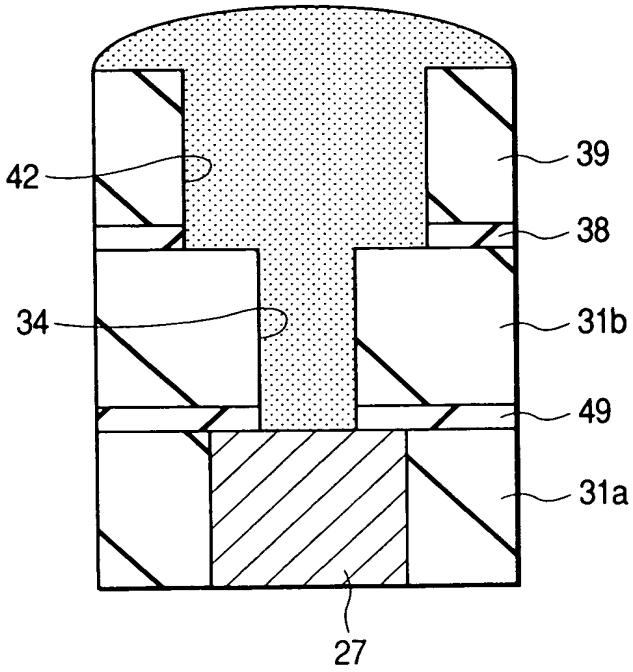


FIG. 79(a)

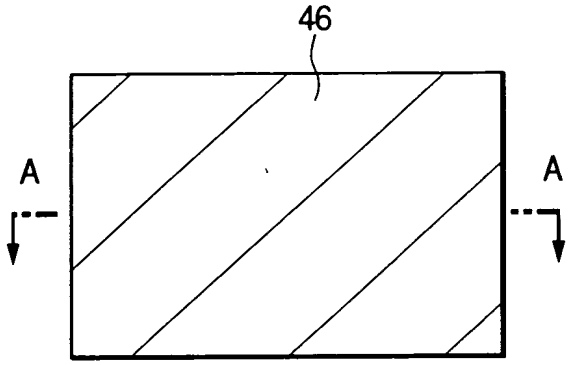


FIG. 79(b)

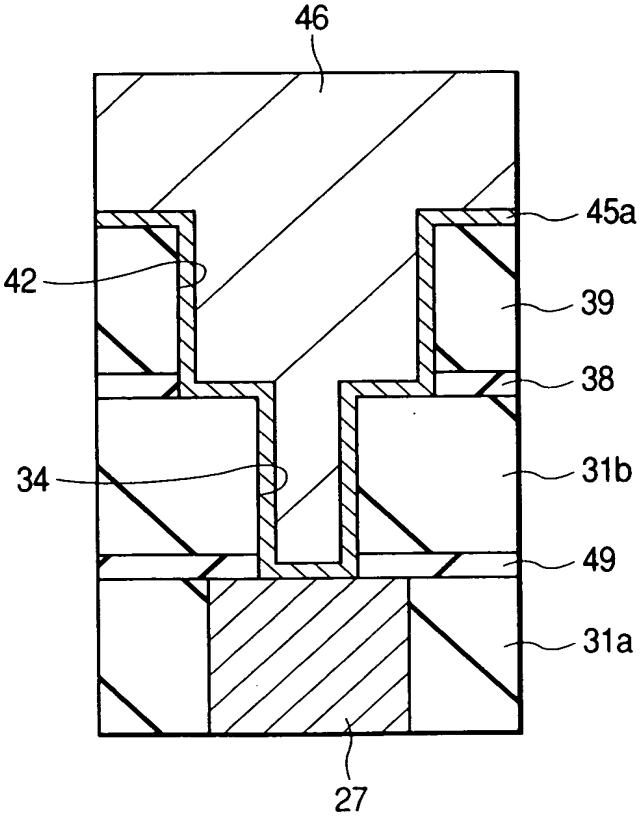


FIG. 80(a)

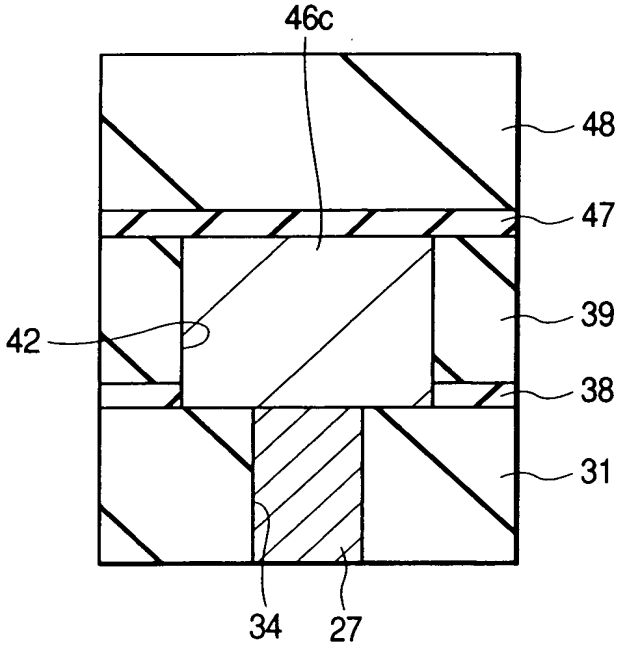


FIG. 80(b)

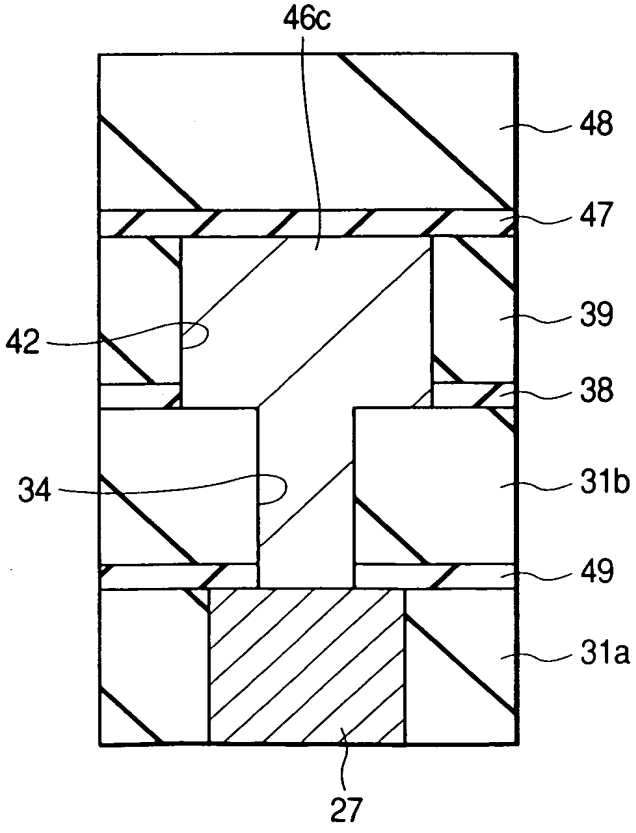


FIG. 81(a)

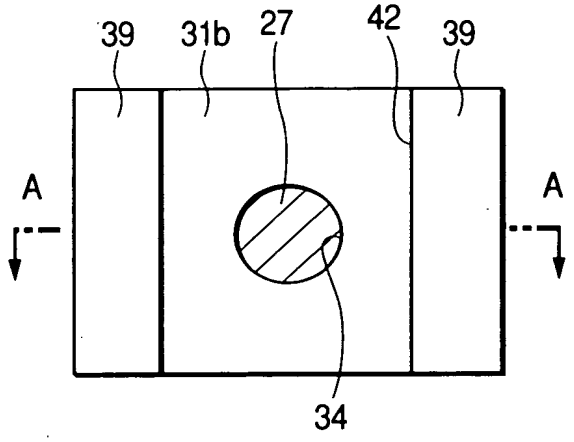


FIG. 81(b)

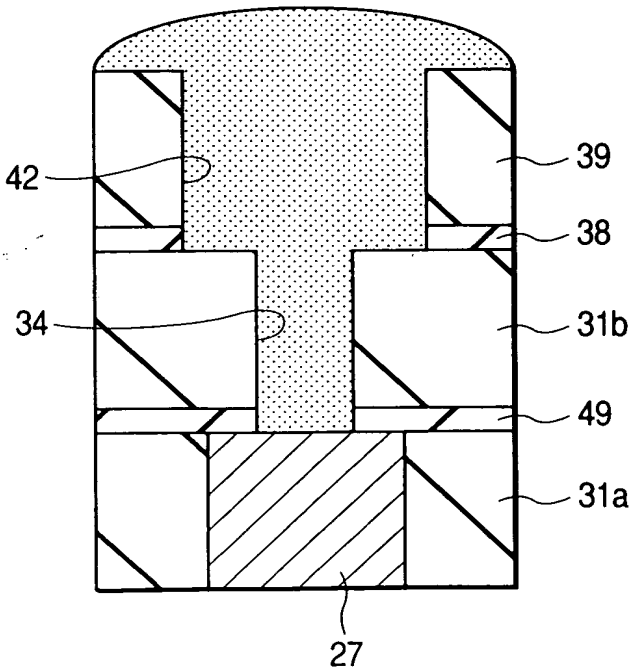


FIG. 82(a)

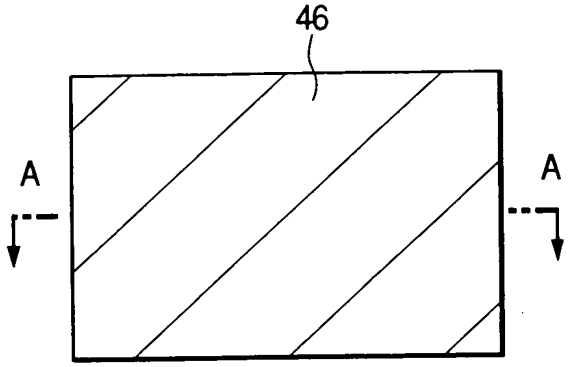


FIG. 82(b)

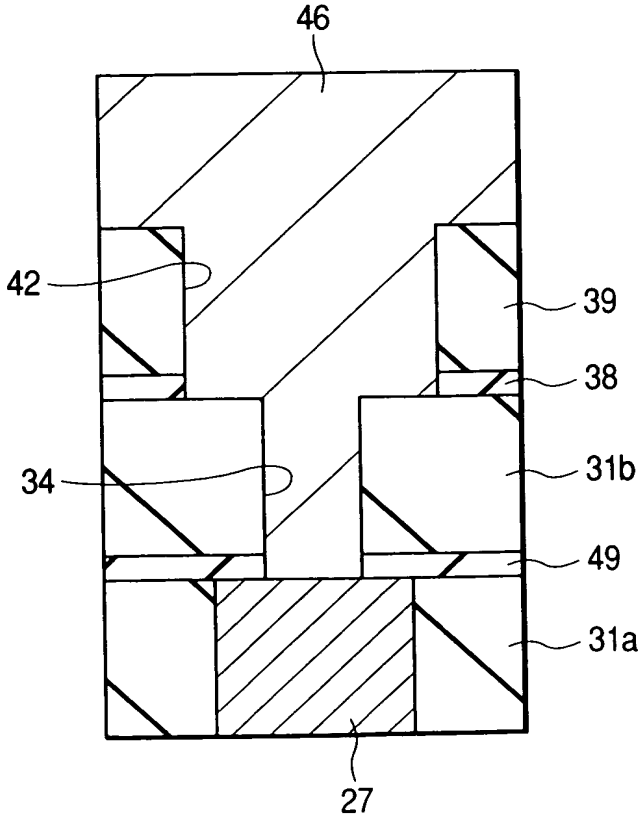


FIG. 83(a)

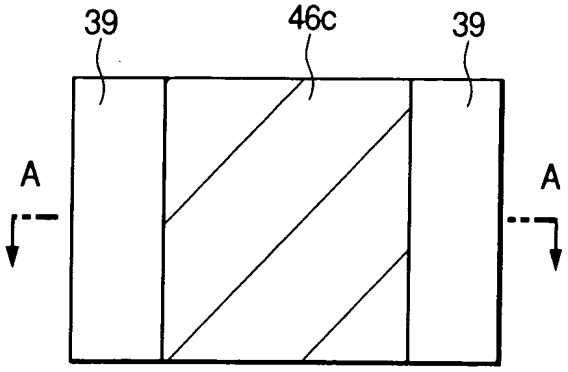


FIG. 83(b)

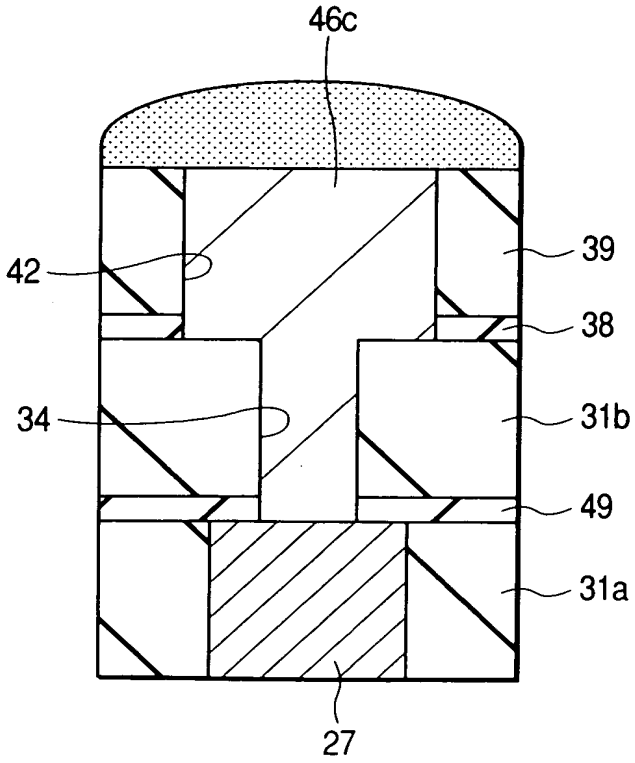


FIG. 84(a)

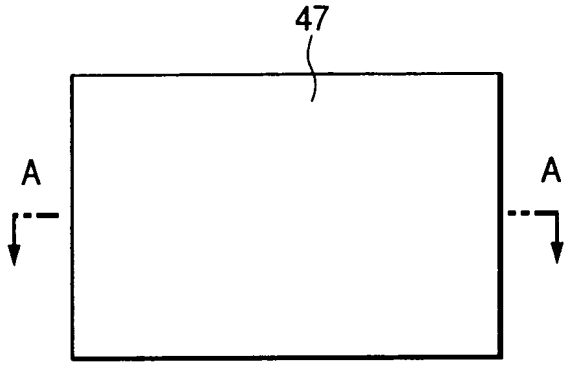


FIG. 84(b)

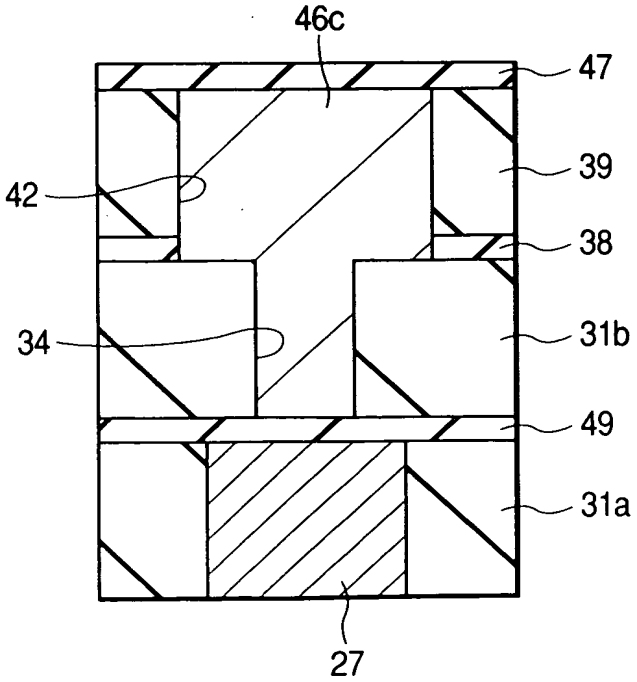


FIG. 85(a)

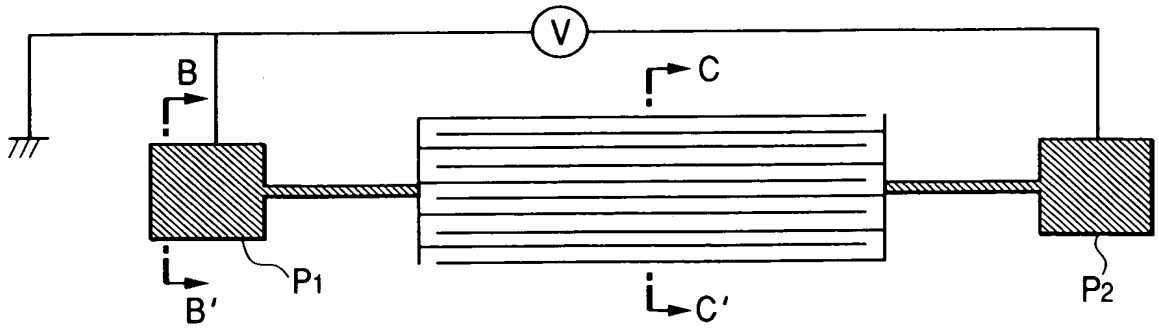


FIG. 85(b)

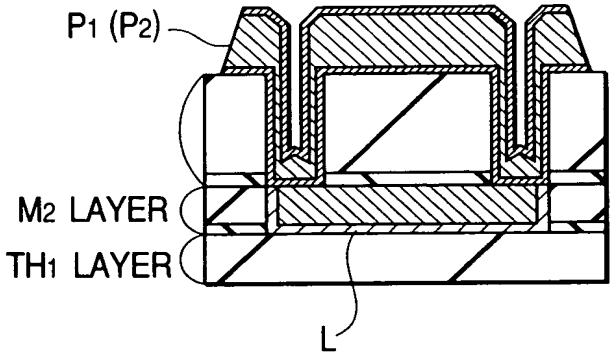


FIG. 85(c)

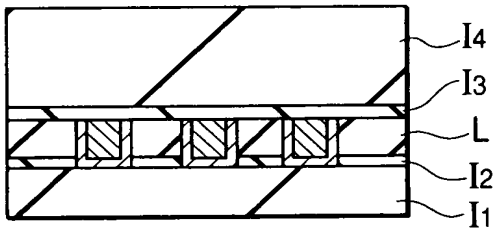


FIG. 86

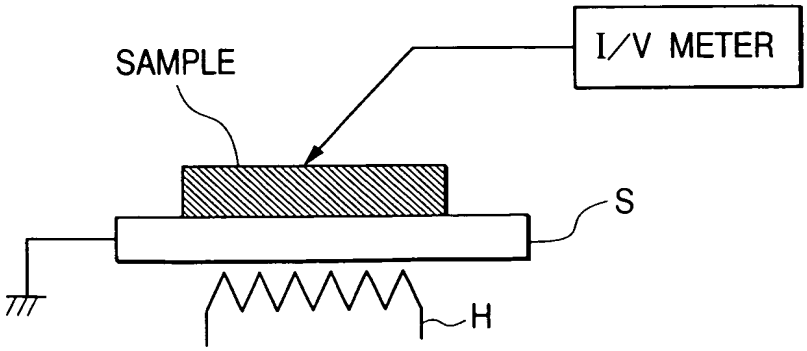
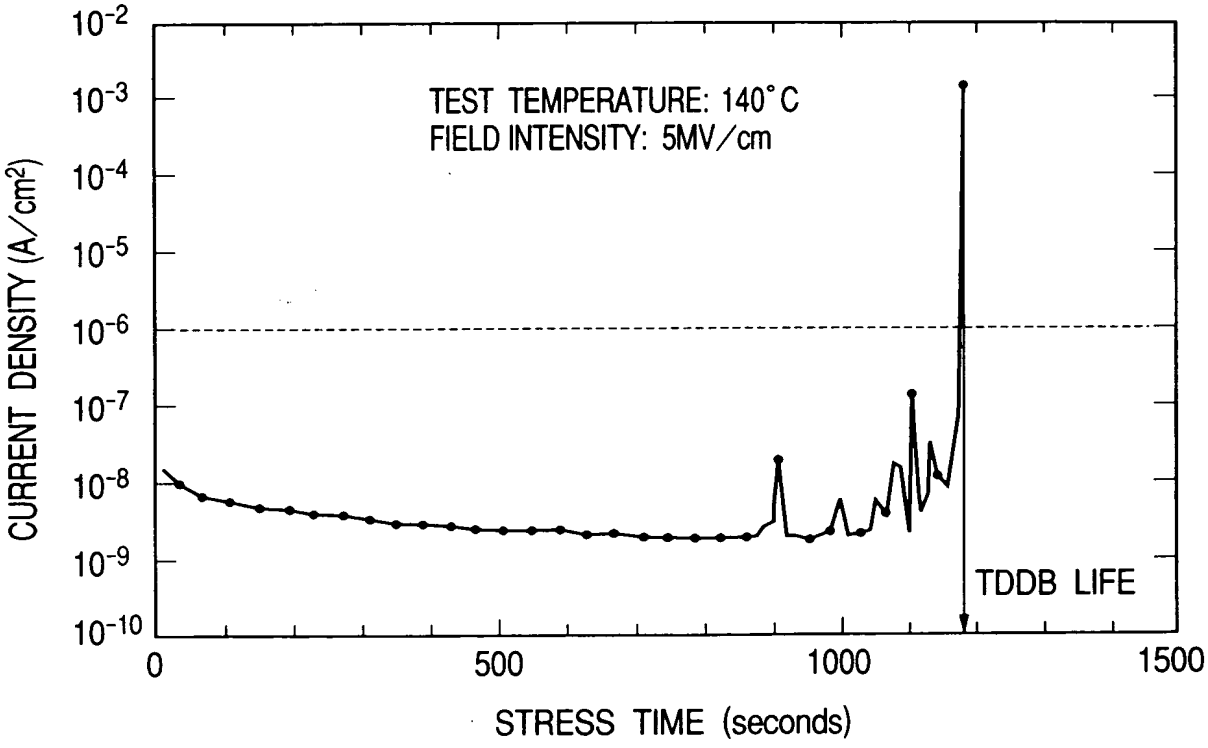


FIG. 87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FIELD INTENSITY: 5MV/cm
TDDB LIFE
CURRENT DENSITY (A/cm²)
STRESS TIME (seconds)
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
0
500
1000
1500

FIG. 88